Columbia Falls Aluminum Company
Initial Review Draft

HEALTH CONSULTATION

Columbia Falls Aluminum Company, LLC

Columbia Falls, Flathead County, Montana

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Prepared by:
Montana Department of Public Health and Human Services
Montana Environmental Health Education and Assessment

Under Cooperative Agreement with:
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Foreword

The Montana Department of Public Health and Human Services (DPHHS) evaluates the public health threat from hazardous waste sites through a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR) in Atlanta, Georgia. This health consultation is part of an ongoing effort to evaluate health effects from contaminated soil, sediment, surface water and groundwater on and near the Columbia Falls Aluminum Company, Limited Liability Company (LLC), site. Montana DPHHS health assessors evaluate site-related public health issues through the following processes:

Evaluating exposure: Health assessors begin by reviewing available information about environmental conditions at the site. The first task is to find out how much contamination is present, where it is, and how human exposures might occur. The United States Environmental Protection Agency (EPA), Montana Department of Environmental Quality (DEQ), and Montana DPHHS staff provided the information for this health consultation.

Evaluating health effects: If we find evidence that exposures to hazardous substances are occurring or might occur, health assessors determine whether that exposure could be harmful to human health. Health assessors focus this report on public health (the health effect on the community) and base our evaluation on existing scientific information.

Developing recommendations: In this report, we outline our conclusions about potential health threats from contaminated soil, groundwater, and surface water. Health assessors also recommend ways to reduce or eliminate human exposure to contaminants. If an immediate health threat exists or is about to happen, we will issue a public health advisory notifying people of the danger and will work to resolve the problem.

Soliciting community input: The evaluation process is interactive. Health assessors start by asking for information from various government agencies, individuals, or organizations responsible for cleaning up the site, and from persons living in communities near the site. We share conclusions about the site with the groups and organizations providing the information. Once we prepare an evaluation report, the Montana DPHHS seeks feedback from the public.

If you have questions or comments about this report, we encourage you to contact us.

Please write to:	Connie.Garrett@mt.gov or: Montana DPHHS Office of Epidemiology and Scientific Support/ Montana Environmental Health Education and Assessment Program 1400 Broadway, P.O. Box 20251 Helena, MT 59620
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Summary

INTRODUCTION

The Montana Department of Public Health and Human Services (DPHHS) has a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) to assess, and make recommendations to prevent, community exposures to hazardous waste.

In this report, we evaluate people's potential exposures to contaminants at the former Columbia Falls Aluminum Company (CFAC) site. The site address is 2000 Aluminum Drive, Columbia Falls, Montana. The industrial portion of the site is 960 acres, north of the Flathead River. From 1955 to 2009, four different companies reduced alumina ore to aluminum there. The plant closed when rising electricity prices made the aluminum reduction business unprofitable.

The Environmental Protection Agency (EPA) listed this site to the National Priorities List on September 9, 2016. The EPA is the lead agency for federal Superfund cleanup. Remediation is occurring with EPA and Montana Department of Environmental Quality (DEQ) oversight. DEQ Hazardous Waste, Asbestos Control, Open Cut Mining, Water Protection, and Federal Superfund programs are involved in the on-going demolition and cleanup activities.

To determine locations and levels of air, soil, or water which will require remediation, consultants test samples. We screen test results to find out which chemicals are found frequently, and at levels high enough to need further evaluation. Then we determine how people might be exposed and estimate what health risks those exposures might have.

Surface soil contamination: Metals, cyanide, dioxin, fluoride, and PAHs are present in site surface soil above residential screening values. Only PAHs and arsenic exceed screening levels for workers, however, tests did not show arsenic above the Montana background soil level. PAHs are incompletely burned organic compounds. Workers and trespassers might be exposed.

Groundwater contamination: Tests showed fluoride, arsenic, cyanide, nitrate, and selenium above drinking water standards in monitoring wells south of the dumps, and north and south of the location of the former factory. Tests of the process wells used when the plant was in operation did not show contamination, and no onsite drinking water wells currently use contaminated groundwater.

Consultants tested groundwater in offsite private drinking water wells north and west of the site, even though these locations are not downgradient of the known groundwater contamination. While private well tests have not found drinking water standard violations, 2013 tests found cyanide in two wells above ATSDR's cyanide screening level. In the conclusions that follow, we explain why we are unsure if these levels could have affected people's health.

Surface water body contamination: Tests of water seeping from the riverbank show groundwater contaminated with cyanide enters the Flathead River south of the former industrial area. The cyanide in this water is just above the level allowed in drinking water. No one uses water in this part of the river as a drinking water source.

Our calculations show skin contact with this water would not present a health threat to fishermen. The riverbank in this area is steep and river bottom is boggy. It is more likely fishermen might fish from a boat. Surface water samples were taken in this part of the river in the Summer of 2018. We will be able to evaluate such exposures soon.

Vapor Intrusion: ATSDR and EPA recognize that volatile chemicals may enter construction trenches and buildings on and near hazardous waste sites. Therefore, we evaluated the soil and groundwater test results and did not find a potential for vapor intrusion.

Workers Exposures: Although we do not have data to evaluate former workers exposures, we summarize and reference what is known from occupational studies of aluminum reduction workers' health effects in Appendix D (Chemical-specific Toxicity Information).

Our conclusions follow. These conclusions could change due to community input or due to new environmental sampling results.

CONCLUSION #1	Workers or trespassers touching onsite surface soil are the most likely to be exposed to site contaminants. They might accidentally swallow contaminated soil they get on their hands. We estimated what these amounts might be and found non-cancer illnesses are unlikely and increased cancer risks are low.
BASIS FOR CONCLUSION #1	We calculated exposure doses for workers and trespassers using averages of surface soil test results. The doses we estimated are far below chronic reference doses and would not be likely to cause non-cancer illnesses. The increased cancer risks we calculated for current and future workers are low for PAHs and arsenic; 4 in 100 thousand, and 2 in 100 thousand, respectively.

The increased cancer risk we calculated for trespassers playing ball (an exposure pathway asked about by residents) in the western part of the site is insignificant, less than 1 in 1 million for exposure to PAHs. The increased cancer risks we calculated for vehicle-riding trespassers (another exposure pathway residents asked about) are low for PAHs, 2 to 3 in 100 thousand; and are very low for arsenic, 1 to 2 in 1 million.

NEXT STEPS #1	We recommend against trespassing on the site, as testing shows areas with concentrated contamination. The highest contamination levels occur in percolation ponds, in ditches leading to percolation ponds and in former waste disposal areas. If trespassers ride ATVs or motorcycles in these areas, they could contact contaminants in mud that could adhere to their vehicles and be transported off the site. A percolation pond is near an open field on the west side of the site. Ball-playing trespassers might incidentally ingest mud containing PAHs if balls land in this pond. Based on our Spring 2018 site visit, trespassing may be less of an issue now than it was in the past. There are many disposal and remediation workers on the site, including during extended working hours. We recommend materials-recycling workers avoid contact with former waste disposal areas. And, we recommend remediation measures prevent future workers' direct exposure to former waste disposal areas.
CONCLUSION #2	We were unable to evaluate exposure levels for residents contacting soil in their yards.
BASIS FOR CONCLUSION #2	Nearby properties may have low level PAHs or other site contaminants which settled from past air emissions. However, consultants have not tested offsite soils or sediments.
NEXT STEPS #2	Test results for recent surface soil samples taken on the site perimeter will allow us to better evaluate if offsite surface soil should be tested. We would recommend testing offsite yard soil for chemicals that were found in soil near the site boundaries.
CONCLUSION #3	Contaminated groundwater should not be used as a drinking water source.
BASIS FOR CONCLUSION #3	Tests found fluoride, arsenic, cyanide, and nitrate above drinking water standards in monitoring wells south of the dumps, and north and south of the potlines. Past production well tests did not show contamination, as these wells are east of the contamination plume. The plant buildings are being dismantled and power to the production wells has been cut off. As a result, workers or others are not currently using water from onsite wells.

NEXT STEPS #3	We recommend prohibiting use of contaminated onsite groundwater as a future drinking water source. This may require on-going testing to track contaminated groundwater movement and a deed restriction prohibiting the use of contaminated groundwater as a drinking water source.
CONCLUSION #4	Private well testing has not confirmed site-related contamination, and we are unsure of the potential for health effects from the low levels of cyanide measured in 2013 testing.
BASIS FOR CONCLUSION #4	Testing in September 2013 found cyanide in two private wells; at levels less than the drinking water standard. It is difficult to say if adverse health effects might be expected because the cyanide levels in these wells were far below levels causing health effects in animals. We do not know if, or for how long people may have been exposed, because confirmation sampling did not find cyanide above the detection level.
NEXT STEPS #4	We recommend continued testing of residential wells near the site to assure no one is using contaminated groundwater.
CONCLUSION #5	The health risks of former workers would have varied based on the area of the plant they worked in, when they worked there, and how long they worked there. However, we are unable to evaluate former workers' exposure risks.
BASIS FOR CONCLUSION #5	Exposure data for former workers is not available. Occupational studies show workers in the early 1950s and 1960s may have been exposed to higher levels of chemicals than later workers. Early process equipment emitted more gases and particulates and there were fewer requirements for personal protective equipment then. Workers in different parts of the plant would have been exposed to different chemicals and at different levels. More years of work would have meant longer periods for exposure.
NEXT STEPS #5	If you are a former worker with health concerns, contact your health care provider. Although your health concerns may not be related to plant exposures, you may choose to tell your health care provider how long you worked at the plant, when you worked there, and what part of the plant you worked in. Appendix D (Chemical-specific Toxicity Information) summarizes what is currently known about health risks for aluminum reduction plant workers from occupational studies.
CONCLUSION #6	Vapor intrusion does not appear to be a potential exposure pathway.

BASIS FOR CONCLUSION #6	Most soil and groundwater testing did not find volatile chemicals: 0.28 µg/L 1,2-dichloroethane was the highest volatile chemical level measured. Our screening calculation showed future unventilated buildings constructed above shallow groundwater with 0.28 µg/L 1,2-dichloroethane would not likely accumulate vapors above the comparison value for indoor air.
LIMITATIONS OF FINDINGS	All risk assessments require the use of assumptions, judgments, and incomplete data. These contribute to the uncertainty of the final risk estimates. Important sources of uncertainty in this health consultation include exposure parameter estimates, use of modeled exposure doses, and current toxicological knowledge. Montana DPHHS health assessors do not know if contamination has reached the soil on nearby properties or offsite sediments. People may be eating fish containing cyanide and PAHs. There may be other exposure pathways for which we lack data. Therefore, this health consultation does not represent an absolute estimate of risk to persons exposed to chemicals near the Columbia Falls Aluminum Company site.
FOR MORE INFORMATION	For further health information about the Columbia Falls Aluminum Company hazardous waste site, contact the Montana DPHHS at (406) 444-5954.

Acronyms and Abbreviations

ARCO	Atlantic Richfield Company
ATSDR	Agency for Toxic Substances and Disease Registry
BPA	Bonneville Power Administration
CAG	Community Action Group
CDD	chlorinated dibenzo-p-dioxin
CFAC	Columbia Falls Aluminum Company
COPC	Contaminant of Potential Concern
CREG	cancer risk evaluation guide
CTE	central tendency exposure (average)
CV	comparison value
DEQ	Department of Environmental Quality
DPHHS	Department of Public Health and Human Services
EMEG	Environmental Media Evaluation Guide
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
FWP	Fish, Wildlife, and Parks
IARC	International Agency for Research on Cancer
IQ	Intelligence Quotient
IRIS	Integrated Risk Information System
LOAEL	lowest observable adverse effect level
MCL	maximum concentration level
mg/kg/day	milligrams per kilogram per day
MRL	minimal risk level
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no observable adverse effect level
NPL	National Priorities List
NTP	National Toxicology Program
PAHs	polycyclic aromatic hydrocarbons
pg/kg/day	picogram per kilogram per day
PHAST	Public Health Assessment Site Tool
RfD	reference dose
RME	reasonable maximum exposure
RSLs	Regional Screening Levels
TAL	Target Analyte List
TEQ	toxicity equivalence
UCL	upper confidence level
µg/L	micrograms per liter
UF	uncertainty factor
VOC	volatile organic compound

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Statement of Issues

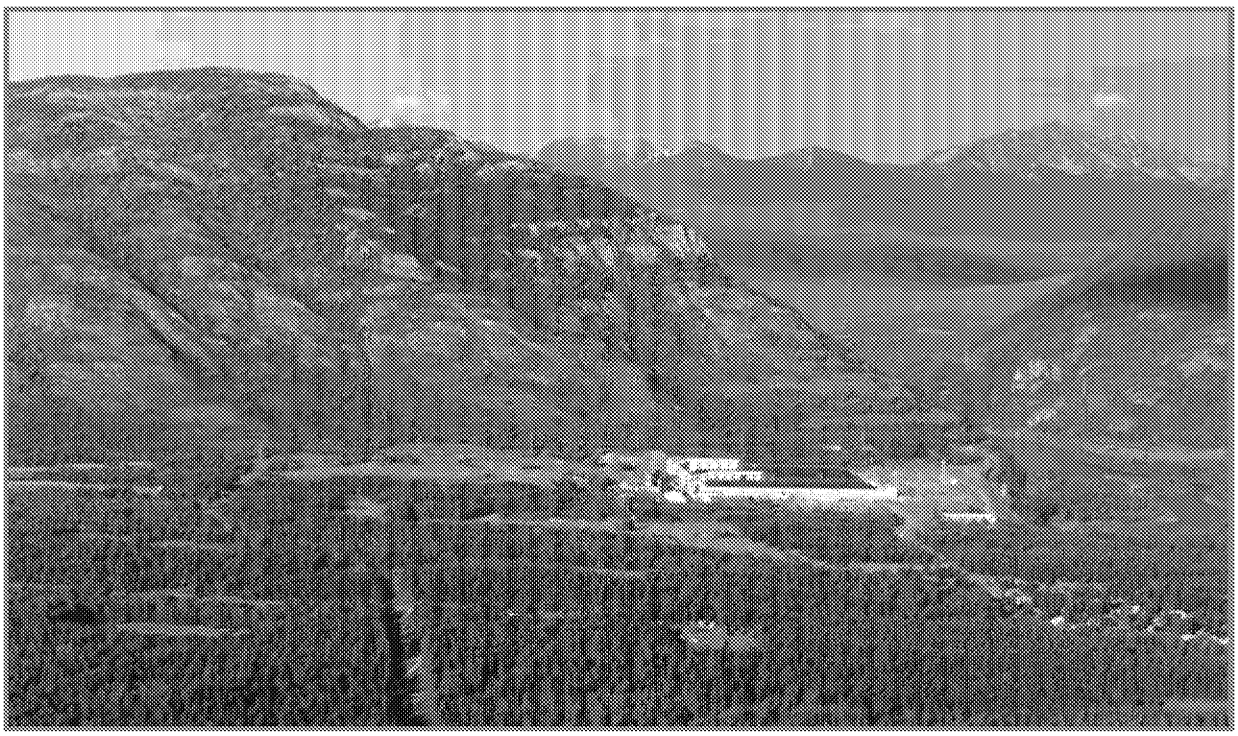
The Montana Department of Public Health and Human Services (DPHHS) assesses the public health risk at the Columbia Falls Aluminum Company site because the United States Environmental Protection Agency (EPA) listed it to the National Priorities List on September 9, 2016. Congress mandated the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) evaluate public health issues at National Priorities List sites. The Montana DPHHS has a cooperative agreement with ATSDR to prepare reports that evaluate public health issues for NPL sites.

DPHHS reviewed available environmental data, researched exposure pathways, and identified the health concerns of nearby residents to address potential harm to peoples' health from site contamination. Exposure estimation requires the use of assumptions, judgments, and possibly incomplete data. These factors contribute to uncertainty in evaluating health threats.

Site Description

The 960-acre industrial portion of Columbia Falls Aluminum Company (CFAC) site is located at 2000 Aluminum Drive, Flathead County, Montana (Figure 1). The industrial portion was an aluminum reduction plant from 1955 to 2009.

Figure 1. Historical photo of Columbia Falls Aluminum Company site, looking east

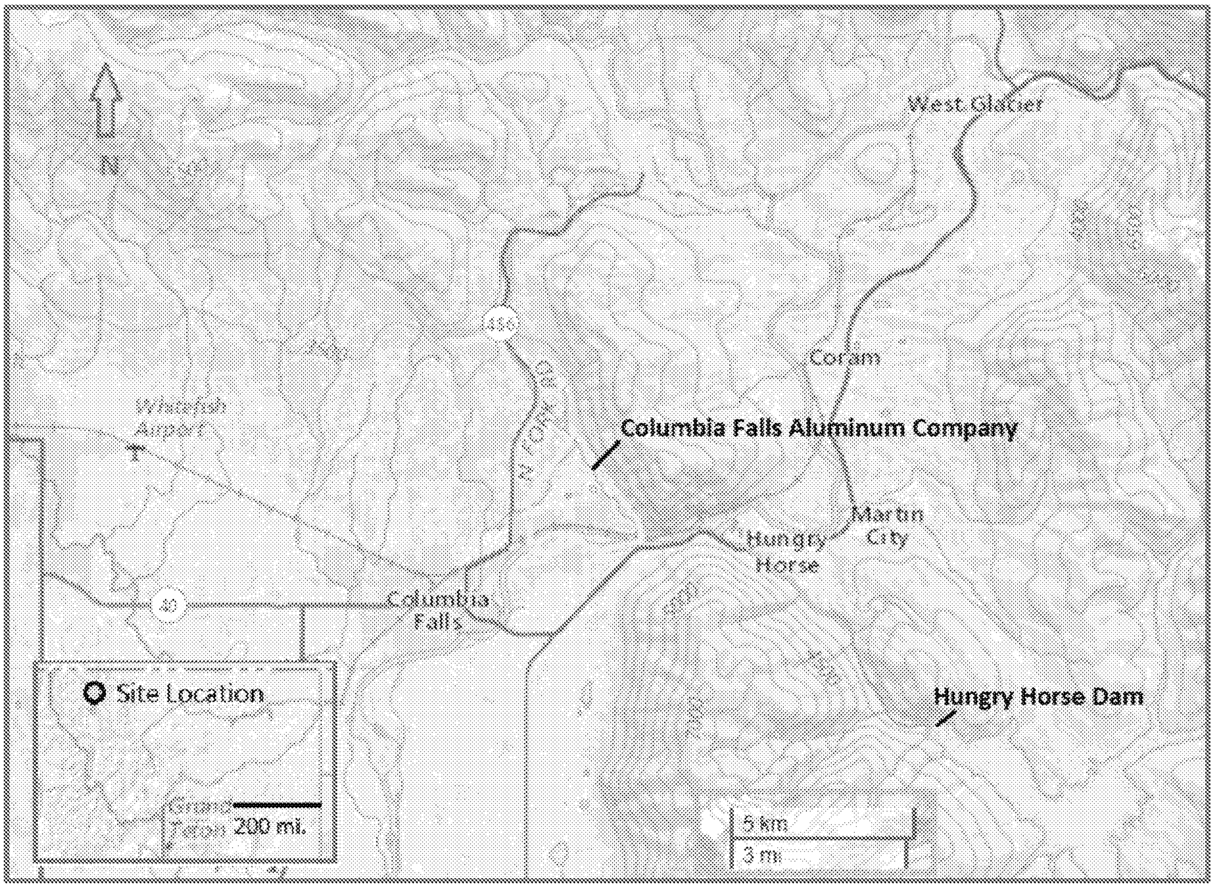


[Hungry Horse News 2015]

The site's total property area covers about 3,196 acres, much of which is south of the Flathead River and was not used for industrial operations.

The outskirts of Columbia Falls border the southwest corner of the site, the Flathead River is south, the Cedar Creek Reservoir is north, and forested lands border the east and west. Some of these forested lands are privately held, and some belong to CFAC. The water bodies near the site borders are Cedar Creek (west) and Cedar Creek Reservoir Overflow (east). Teakettle Mountain rises 2,000 feet east of the site (Figure 2).

Figure 2. Columbia Falls Aluminum Company site location



[USGS 2016]

The Montana DPHHS author visited the site on May 9th, 2018 as a site tour participant. The facility has many contractors working on it. We saw demolition machinery and debris. Contractors are mining rock on the site to fill in the basements exposed by demolition of the production portions of the facility. The site is partially fenced and has perimeter warning signs (Figure 3).

Figure 3. Columbia Falls Aluminum Company site entry sign at locked gate

[DPHHS photograph, May 9, 2018]

Site History and Remediation

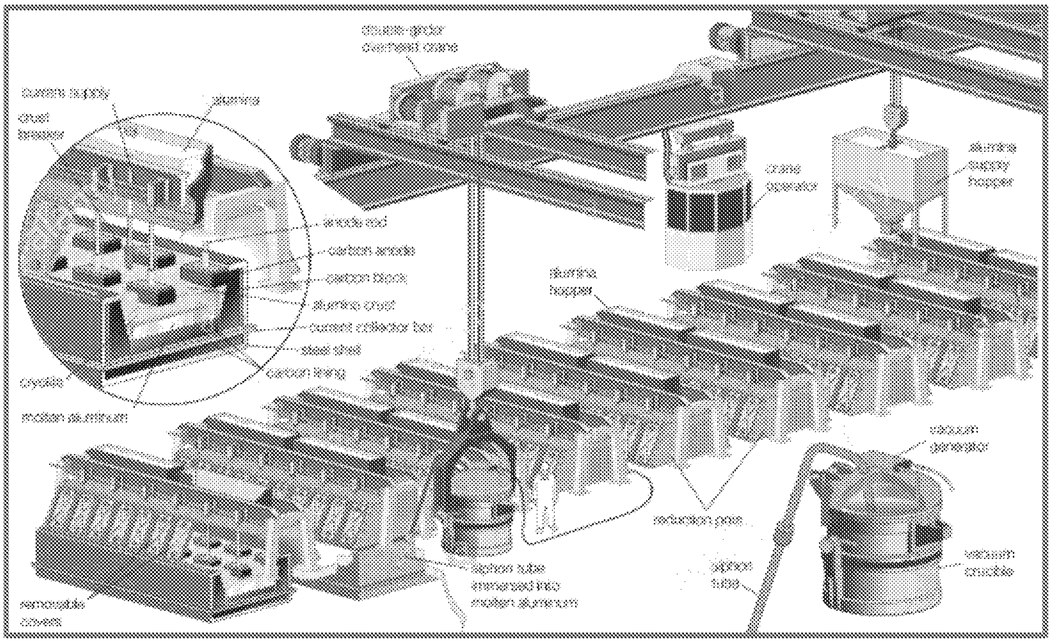
Site ownership: In 1949, Harvey Machine Company acquired options for an aluminum plant and chose its location due to its proximity to the Hungry Horse Dam hydroelectric power source (Figure 2). Anaconda Copper Mining Company bought 95 percent of Harvey's interests in 1951.

The Anaconda Company constructed two paired-lines of ore reduction cells, called potlines, in 1953 and 1955. They started both potlines in 1955. Anaconda constructed a third potline which started in 1965; and later fourth and fifth potlines, which started in 1968. At peak production, the plant produced 360 million pounds of aluminum per year. This amount was approximately one-fifth of the 2016 US aluminum production level.

In January 1977, Atlantic Richfield Company (ARCO) purchased the company from the Anaconda Company. ARCO operated the plant nearly eight years, selling the company to the Montana Aluminum Investors Corporation in September 1985. Aluminum Investors Corporation operated the plant as Columbia Falls Aluminum Company. Glencore Agriculture purchased the plant in May 1999 and operated it under the same name until 2009, permanently closing the plant in March 2015.

Aluminum reduction process: Figure 4 illustrates the potline parts. Aluminum reduction uses a sodium, aluminum, and fluoride melting agent to dissolve aluminum oxide ore material. Once dissolved at high temperature, electrolysis separates out the molten metal. The process uses direct electric current to heat the components and polarize the liquid in large carbon-lined steel containers called reduction pots. The direct current flows between a carbon anode (positively charged) made of coke and pitch, and a cathode (negatively charged) formed by the carbon pot lining [rocksandmineral.com, 2017].

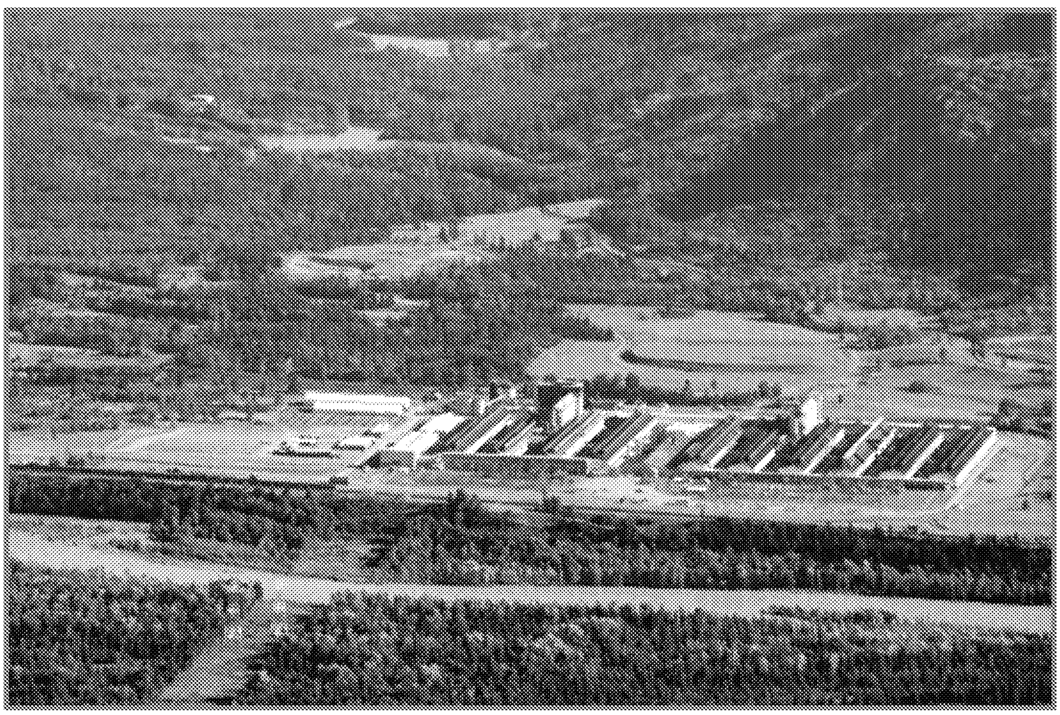
Figure 4. Aluminum reduction process schematic showing potlines



[Alamay.com 2017]

Aluminum reduction plants align these pots in long rows. Each row of pots is electrically connected in series: two rows of pots form one set, called a potline. The five potlines at CFAC had 600 pots. Figure 5 is a historical picture of the site.

Figure 5. Columbia Falls Aluminum Company, historical aerial photograph, looking north, showing 10 linear buildings forming 5 potlines



[Flathead Beacon, June 2014]

Smelting is a continuous, year-round process. If a power supply failure interrupts production for more than four hours, the metal in the pots hardens, requiring an expensive rebuilding process. Workers remove molten aluminum from the pots every 48 hours and cast it into ingots in the casting garage.

The Columbia Falls Aluminum Company reduction plant operated for 54 years. High electricity prices made the business unprofitable and it closed in 2009.

Figure 6 shows past and present site features. These included a 1.75 million-square-foot factory that housed north-south oriented lines of reduction cells, a rod mill, paste plant, ore and operations materials storage buildings, offices, laboratories, mechanical shops, petroleum coke and pitch tanks, pump houses, and a casting garage. The site also has waste chemical sources: eight landfills, two leachate ponds, former material loading and unloading areas, and several wastewater percolation ponds. A rectifier yard owned by Bonneville Power Administration and a switch yard and railroad right-of-way owned by Burlington Northern Railroad lie within the site's boundaries.

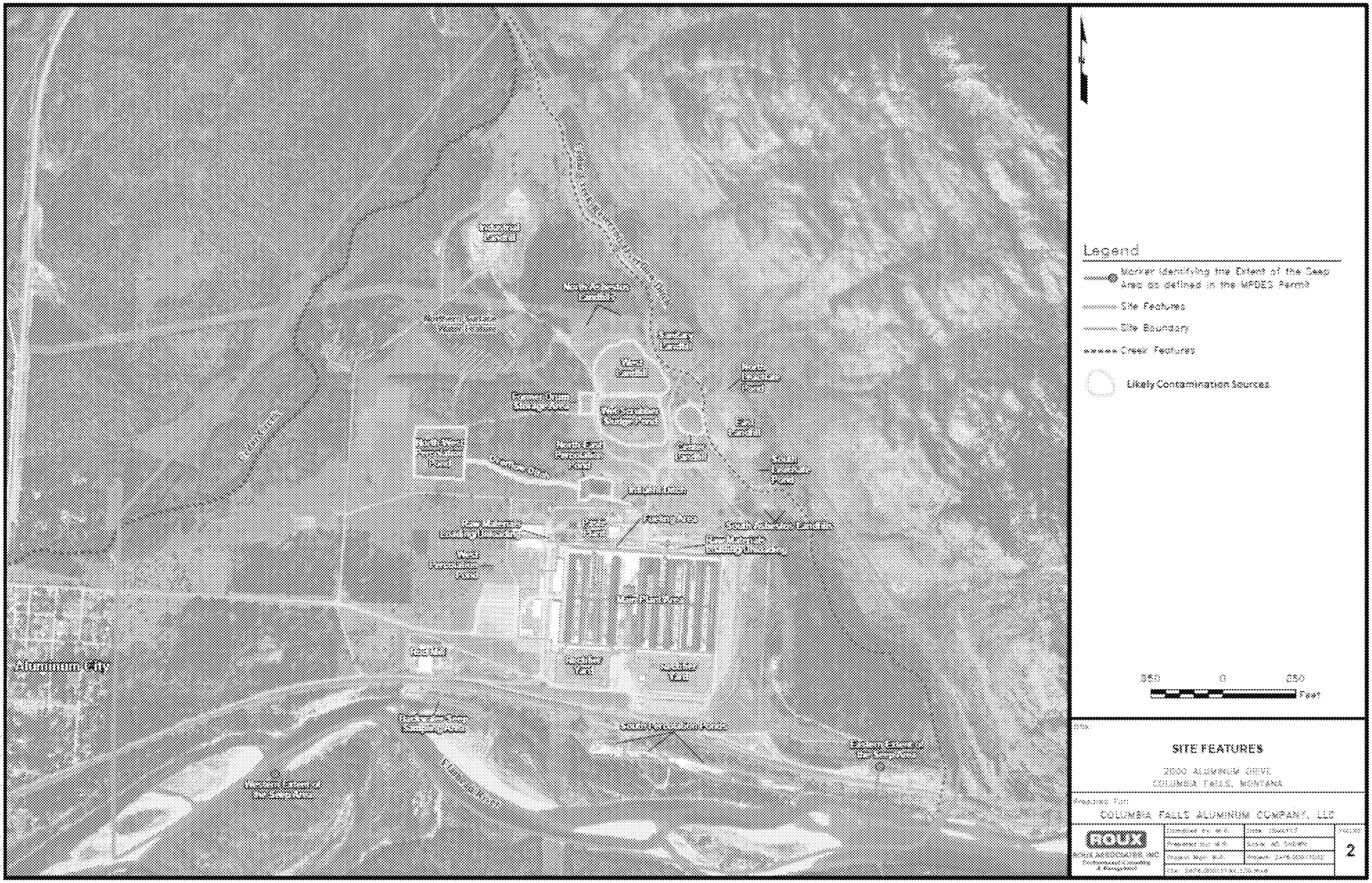
To determine locations and levels of chemicals which will require remediation, contractors tested soil, sediment, groundwater, and surface water. Process and material storage areas, waste disposal areas and air emissions are or were the sources of site-related contamination (Figure 6). Contaminants include:

- cyanide, fluoride, nitrate, and PAHs and dioxins (which are chlorinated organic chemicals), and
- metals, (included for completeness as fewer than 1% of surface soil samples contained aluminum, arsenic, copper, and nickel above their comparison values, and a few groundwater samples contained antimony, manganese, selenium and vanadium above their comparison values).

The site owner — CFAC-Glencore — is currently remediating the site with EPA and Montana DEQ oversight. DEQ Hazardous Waste, Asbestos Control, Opencut Mining, Water Protection, and Federal Superfund programs are involved. The EPA is the lead agency for Federal Superfund proposed cleanup under the National Priority Listing (NPL).

In 2015, Calbag Resources purchased the physical aluminum plant infrastructure. As of December 2017, Calbag recycled or reused 262,694,803 pounds of building materials and took 16,553,828 pounds of waste to landfills, primarily from dismantling buildings [Cityofcolumbiafalls.org 2018]. Hazardous wastes included 69,900 pounds of regulated asbestos waste and 4,893,980 pounds of non-regulated asbestos waste from insulation materials that protected workers from heat [DEP 2018a]. Structures undergoing removal included the West Rectifier, Rod Mill Building, Paste Plant, Quonset Hut, West Alumina Unloader, Compressor Building, Laboratory, Building 1, and the Change House.

Figure 6. Columbia Falls Aluminum Company Site, site features and contamination source areas



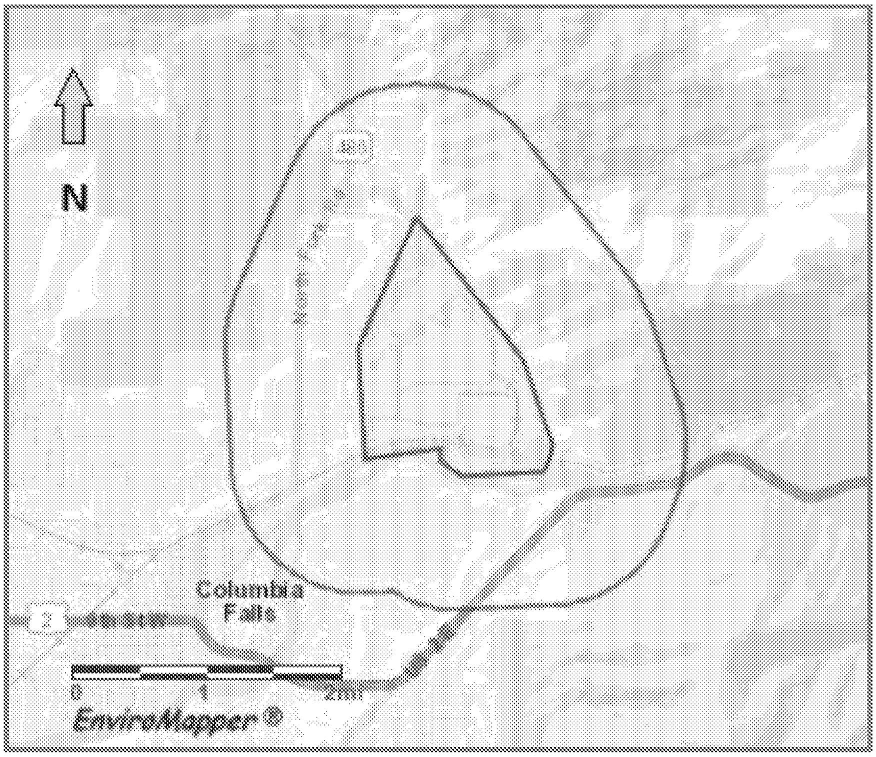
[Roux 2017]

Demographics

Figure 7 shows the area within one mile of the site in yellow. The 2011-2015 census estimated 901 people lived in this area. Census estimates for this period include 95% white, 3% American Indian, and 2% reporting as two or more races or other [EPA 2017c]. No churches or child day cares are within 1 mile of the site [Google Maps 2018].

Within a mile of the site, 82% of households own their homes, and 77 % have annual incomes at $25,000 or above. Of those 25 years old and older, 42% are high school graduates and 19% have education beyond high school.

Figure 7. Area within one mile of the Columbia Falls Aluminum Company site



[EPA 2017c]

Climatic and Meteorological Conditions

The Columbia Falls area climate varies with four distinct seasons. From November through March, Winter temperatures average below 32° F. From June through August, Summer temperatures average in the 60s and 70s, with highs in the 80s. Annual precipitation averages 9 inches of rainfall and 26 inches of snow. Frozen soils and snow limit the amount of time workers or trespassers might get surface soil on their hands and incidentally ingest it thorough hand-to-mouth activities.

The past impacts of air emissions on the public would have varied with wind direction and windspeed. Typically, wind patterns are collected at airports or other locations where meteorological towers are found. For the Columbia Falls area, the closest airport is near

Kalispell at the Glacier Park International Airport, about 8 miles south-southwest of the site.

Wind directions and speed are measured on an hourly basis and a historical record is maintained. Historical records show winds are from the south, at 3 to 5 miles per hour, roughly 11% of the time [USDOA, 2018]. About 8% of the time, the winds are from the southeast, more often at 3 miles per hour. These are the primary wind directions. Winds change with time of day; surface temperature differences brought about by sunlight can cause greater local wind movement during daylight hours.

Discussion

Evaluation Process

Health assessors compare sample test results with soil, water, and air comparison values (CVs) and regional screening levels (RSLs) [ATSDR 2018, EPA 2018f]. CVs and RSLs are chemical concentrations below which we do not expect harm to health for daily long-term exposures as would occur with residential exposures. Health assessors retain chemicals measured above these screening values for further evaluation, as contaminants of potential concern (COPCs).

Environmental Data

The sample test results we evaluated came from the following reports.

In the CFAC Site Reassessment, EPA's consultants reported test results for the following samples [Weston 2014]:

- 1 background, 10 onsite monitoring, and 5 residential (drinking water) groundwater wells,
- 5 background and 11 surface water samples from Cedar Creek, Cedar Creek Overflow Drainage, and Flathead River, and
- 6 background and 14 site sediment samples.

Weston analyzed water samples for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs,) and total and dissolved Target Analyte List (TAL) metals, fluoride, and nitrate/nitrite. They tested sediments and 2 background soil samples for these same analytes, except dissolved metals and nitrate/nitrite. Weston tested 6 onsite soil samples, but only for fluoride.

In the CFAC Phase I Site Characterization [Roux 2017a], Glencore's consultants, Roux, tested surface soil samples for VOCs, SVOCs, pesticides, PCBs, TAL metals, total and free cyanide, and fluoride. They tested:

- 189 onsite surface soil samples,
- soils within the Asbestos Landfills 15 test pits for asbestos (asbestos pipes or bags were found in 3), and
- 8 background samples, with surface soil samples.

Roux tested filtered and unfiltered groundwater samples for TAL metals, VOCs, SVOCs, total and free cyanide, fluoride, and nitrate and nitrite. They tested filtered and unfiltered surface water samples for metals and free cyanide; and unfiltered water samples for total cyanide. They also tested for other water characteristics; alkalinity, hardness, chloride, sulfate, total suspended and total dissolved solids from these locations:

- 63 site-wide monitoring wells, and 17 residential (drinking water) wells;
- 10 onsite surface water samples; 3 from the South Percolation ponds, 5 from the Cedar Creek Reservoir Overflow Ditch, and 2 from surface water seeps east of the Industrial Landfill.
- 22 surface water and sediment locations; 6 from the Flathead River, 3 from Cedar Creek, 5 from the Cedar Creek Reservoir Overflow Drainage, and 8 from onsite seeps.

In the CFAC Groundwater and Surface Water Summary Report, Roux [2017b] retested groundwater and surface water samples for TAL metals, VOCs, SVOCs, total and free cyanide, fluoride, and nitrate and nitrite, to better characterize site groundwater and surface water conditions. Roux also tested for other water characteristics; alkalinity, hardness, chloride, sulfate, total suspended and total dissolved solids. They sampled wells and surface water locations with sufficient water in four sampling episodes:

	# Monitoring Wells	#Surface Water Locations
· September 2016	60	12
· December 2016	58	17
· March 2017	61	13
· June 2017	63	23

For each well or surface water sample location, we tallied the highest value for a chemical exceeding its comparison value.

After screening data from these three reports using ATSDR residential screening values for soil exposure and groundwater used as a source of drinking water, we found the following contaminants of potential concern*:*

- in onsite surface soil — primarily PAHs and fluoride. Aluminum, arsenic, copper, cyanide, dioxin, and nickel occurred infrequently; one or twice above residential screening values.
- in onsite sediment — primarily PAHs, Aluminum and arsenic occurred once above residential screening values and the arsenic value was not above the Montana background.
- in onsite surface water — cyanide occurring twice and fluoride occurring once above drinking water standards. This surface water is not a drinking water source.
- in onsite groundwater —arsenic, cyanide, fluoride, nitrate, and selenium above drinking water standards, and manganese, antimony, and vanadium above screening levels.

Exposure Pathways

To evaluate the risk of harm to public health from site-related chemicals, health assessors look at ways people could be exposed to these contaminants, called exposure pathways. Chemical contamination in the environment might harm your health but only if you have contact with those contaminants (exposure). Without exposure, there is no harm to health. If there is exposure, how much of the contaminants you contact (concentration), how often you contact them (frequency), for how long you contact them (duration), and the danger of the contaminant (toxicity) all determine the risk of harm.

Knowing or estimating the frequency with which people could have contact with hazardous substances is essential to assessing the public health importance of these contaminants. To decide if people can contact contaminants at or near a site, we look at human exposure pathways.

Exposure pathways have five parts, including:

- a *source* of contamination such as surface soil, groundwater, or airborne dust;
- an *environmental medium* to hold or transport the source; such as air, soil, or water;
- an *exposure point* where people contact source chemicals;
- an *exposure route* through which source chemicals enter the body; and
  an *exposed population.*

We eliminate an exposure pathway if at least one of the five parts referenced above is missing and will not occur in the future. Exposure pathways not eliminated are either completed or potential. For completed pathways, all five pathway parts exist and exposure to a contaminant has occurred or is occurring. For some potential pathways, exposures may occur in the future; for others, exposures may never occur.

For this assessment, we evaluated the health threats from onsite contaminants and offsite drinking water well test results. For the completed and potential exposure pathways, CFAC is the source of contaminants. Contaminants came from waste disposal and general operations involving aluminum reduction chemicals. Contaminated soil, sediments, surface water, and groundwater are the contaminated onsite media.

Phase I sampling identified areas of contamination on the site. Some Phase II samples taken this summer (2018) are near the edges of the site and in surface water that drains into the Flathead River. Test results from these Phase II samples will allow us to determine if additional offsite testing needs to be done. Currently available offsite test results are only for groundwater.

Completed and Potential Exposure Pathways (Table C-1)

Exposures to contaminants in surface soil or sediments might occur via incidental ingestion (swallowing soil from mouth contact with dirty hands or gloves), skin contact, or inhalation of windblown dust. Such exposures could be occurring now or could have occurred in the past. Potentially exposed groups include onsite workers and trespassers and offsite residents.

The riverbank near the Flathead River contain sediments contaminated by plant discharges and surface water contaminated by groundwater seeps. The riverbanks are steep and the water exiting the seeps makes the soil boggy. While fishing access to the Flathead River there would be difficult due to the muddy banks and river bottom, the seeps are on the site. People accessing this land would be trespassers.

Fishing access in the cut-off channel near the seeps might be more likely from a boat. The highest measured cyanide levels in seep surface water are just above drinking water standard, 200 µg/L. Using an assumed incidental ingestion of 120 milliliters water per hour during swimming (the standard DEQ exposure assumption), a person would have to swim 8 hours per day, every day, to equal equivalent drinking water exposure. Our dermal calculations show skin exposure would result in exposure 2000 times less than the Minimal Risk Level.

Although we evaluated the occurrence of low cyanide levels in private well groundwater, it is not clear what the levels measured in 2013 testing mean. Additional testing did not measure cyanide above the laboratory detection limit.

Recent groundwater studies on the site show groundwater flowing south and not toward areas with residential wells. Because contamination was not confirmed, and private wells are not downgradient of the area of contaminated groundwater, we do not consider private well water ingestion a potential exposure pathway. Nevertheless, continued testing will assure people they are not drinking contaminated groundwater in the future. Test results from additional monitoring wells installed in the western portion of the site near residences (in the Spring and Summer of 2018) will further define groundwater flow direction and contaminant levels.

Plant emissions are past completed exposure pathways. Workers and nearby residents would have been the exposed population. Plants and animals were also exposed. While DPHHS does not have past data to review to determine possible health outcomes, historical reports and the enactment of air pollution laws indicate that emissions occurred in the past (Appendix E). Because the plant closed in 2009 and has been dismantled, plant emissions are an eliminated exposure pathway.

Eliminated Exposure Pathways (Table C-2)

Exposure pathways may be eliminated because a media had chemicals above comparison values, but no one is exposed now, and it is not likely they will be exposed in the future. Another reason to eliminate an exposure pathway is because testing did not find contamination.

In the case of volatiles, to make the determination that testing did not find chemicals above their comparison values, we took the highest values measured and used ATSDR's Vapor Intrusion Guidelines to determine a comparison value. Our calculations show onsite vapor levels of chemicals in soil would be below the calculated comparison value (Appendix B). Therefore, workers would not be exposed to vapors in trenches they might dig, or inside future buildings through a process called vapor intrusion. Therefore, we eliminated the vapors and vapor-intrusion exposure pathways.

Plant process wells were not contaminated in the past and do not have power sources on their pumps now**.** Therefore, we eliminated the ingestion and dermal contact with contaminated onsite groundwater exposure pathway for past and current workers. Because tests show arsenic, cyanide, fluoride, and nitrate levels in onsite groundwater exceed enforceable drinking water standards, we recommend remediation requirements include deed restrictions prohibiting the use of contaminated site groundwater as a source of drinking water. If deed restrictions prevent workers' future use of contaminated site groundwater, we could eliminate contaminated onsite groundwater as a future exposure pathway.

Workers' and trespassers' onsite, and residents' offsite exposures to contaminants in surface water via ingestion (swallowing surface water) and skin contact could be occurring now or could have occurred in the past. According to the Montana DEQ and Administrative Rules of Montana Chapter 30, Water Quality, Sub-chapter 6, no uses Cedar Creek, Cedar Creek Reservoir runoff ditch, or the Flathead River as a drinking water source [ARM 2003]. People who might swim or fish in these water bodies will not drink 1 to 2 liters of water daily, every day, like residents who might use surface water for drinking water. Dermal calculation for the highest seep cyanide level also showed the dermal contact exposure dose would be below the Minimal Risk Level. Therefore, surface water may not be an exposure pathway for ingestion, as a drinking water source or for dermal contact. We will evaluate the test results for the additional samples taken in 2018 to determine whether the surface water exposure pathway can be eliminated.

Pathway Analysis and Health Evaluation

If site-related chemicals are present in completed or potential pathways, we try to determine if the measured levels could be harmful to people. We use an ATSDR tool to estimate amounts of a contaminant that people contact and get into their bodies. This method uses specific exposure parameters from the EPA Risk Assessment Guidelines to calculate an amount per weight, or **dose** [EPA 2011].

We include an in-depth explanation of the dose calculation method we use, called the Public Health Assessment Site Tool (PHAST) and examples of completed dose calculations in Appendix B. While this tool uses EPA's exposure assumption guidelines, it may be more conservative than an EPA Human Health Risk Assessment. ATSDR calculates health risks for a range of childhood weights and uses both average and reasonable maximum exposure assumptions. We also screen volatiles in groundwater for vapor intrusion using recommendations in the ATSDR Vapor Intrusion Guidance Model which differs from EPA's Vapor Intrusion Screening Level Calculator.

Health assessors compare each calculated exposure dose to a corresponding health guideline, typically an ATSDR Minimal Risk Level (MRL) or EPA Reference Dose (RfD), for that chemical [ATSDR 2018, EPA 2018g]. Health guidelines are considered safe doses; that is, if the concentration or calculated dose is at or below the health guideline, we expect no adverse health effects. If the calculated doses exceed their health guidelines, we use toxicological studies to estimate potential health effects and discuss those possible health effects in the following section.

We included toxicological information for each chemical of potential concern and specific types of cancer linked with site-related carcinogens in Appendix D.

Off-site Exposure Pathways and Health Evaluations

Residents exposures to surface soil, sediment, dust, or emissions pathways

Test results from Phase II site perimeter sampling will allow us to evaluate whether offsite surface soil should be sampled. Offsite exposure pathways for residents could include exposures to contaminants in surface soil via incidental yard soil ingestion, or windblown dust inhalation. Nearby residents might also be exposed to offsite sediments.

A past offsite pathway could have been residents' inhalation exposures to contaminants in plant emissions. Historical air data is available for a few specific properties for limited amounts of time. These data indicate air quality was a problem from the aluminum reduction plant and other sources.

Residents exposures to groundwater (from private drinking water wells)

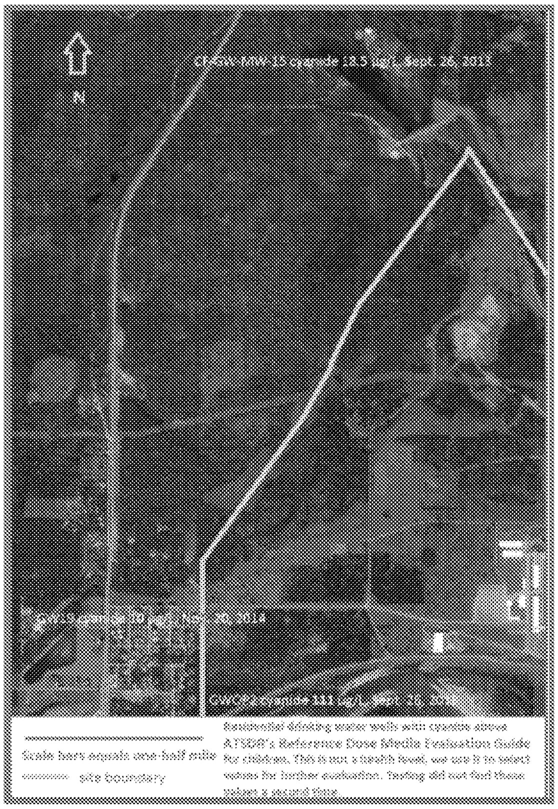
To address the potential for offsite groundwater contamination, consultants have tested private drinking water wells near the site since 2013 [Weston 2013, Roux 2017a]. Testing has not found contamination above drinking water standards [Roux 2017] (Figure 8a, Table C-6). However, some cyanide levels detected in groundwater in 2013 were above ATSDR's chronic Reference Dose Media Evaluation Guide for children, 4.4 micrograms per liter (µg/L).

Testing in September 2013 found three wells with 10, 18.5 and 111 µg/L cyanide, respectively [Weston 2013]. Weston improperly sampled the well with the highest cyanide level (through a garden hose), so we did not evaluate the 111 µg/L cyanide test result. Based on map location, it appears CFAC's consultant sampled the well with the test result of 111 µg/L cyanide 14 times in 2015 and 2016 and did not detect cyanide [Roux 2017b].

We calculated residential doses for persons who may have drunk well water with 10 µg/L and 18.5 µg/L cyanide, although follow-up testing did not confirm these cyanide levels. So, we do not know for sure if, or for how long people might have been exposed. For an estimated average exposure scenario, both cyanide levels exceeded the reference dose for birth to 1-year-olds (Table C-9). For the maximum exposure scenario: at 10 µg/L, the doses for birth to 2-year-olds exceeded the reference dose; and at 18.5 µg/L, all ages and pregnant women exceeded the reference dose.

In the reference dose animal study, cyanide exposure adversely affected the development of the male reproductive system [EPA 2018a]. This study showed that chronic exposure (that is, greater than 1 year) to cyanide caused the cauda epididymis to be smaller. The cauda epididymis is the third and last part of the tube connecting a testicle to the vas deferens in the male reproductive system. It stores maturing sperm and it is where sperm gain their ability to swim.

Figure 8a. Locations of private wells with cyanide greater than 4.4 µg/L (chronic child Reference Dose Media Evaluation Guide) near the CFAC site.



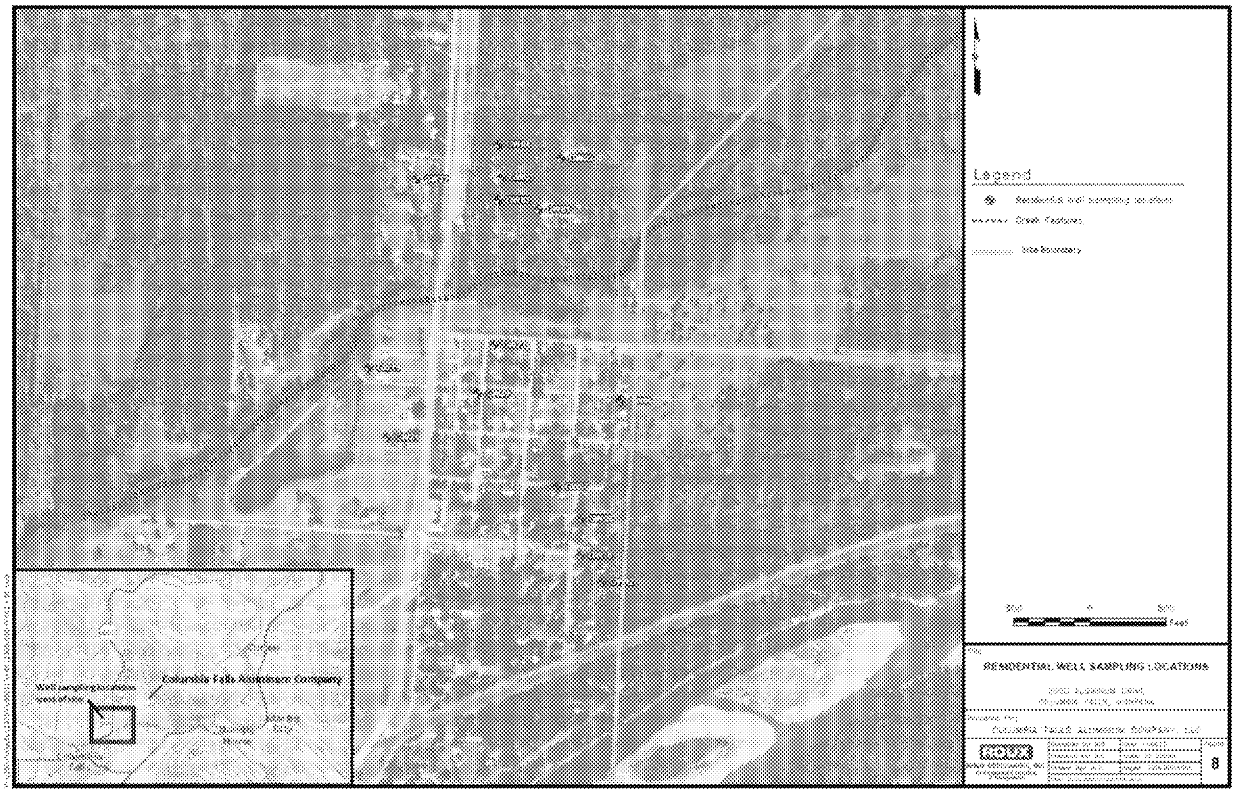
[Weston 2014]

To compare this research to risks in people, the EPA divided the study effect level by a large Uncertainty Factor (Appendix D). Because of the large uncertainty factor, the highest dose we calculated is 731 times less than the dose at which scientists measured a decrease in animals' cauda epididymis weight; however, this dose is 4 times more than the reference dose, so we hesitate to rule out the risk of harm to health.

EPA has not classified cyanide as a carcinogen.

The following map (Figure 8b) shows the locations of the 17 private wells tested for CFAC [Roux 17b]. Although these test results did not find chemicals above their comparison values, we recommend continued testing of offsite private wells to reassure nearby residents.

Figure 8b. Private wells tested by CFAC's consultant, Hydrometrics



[Roux 2017]

Onsite Exposure Pathways and Health Evaluation

Trespassers' exposures to onsite soil

The Columbia Falls Community Action Group website noted "in spite of 'no trespassing' signage near the site, people continue to access the area to play ballgames and ride motorcycles and ATVs" [CAG 2018]. Because of these comments and because the site is not completely fenced, we separated the data into two areas to evaluate trespassers' potential levels of exposure. Ball games might be played on the flat, tree-less areas on the western part of the site. Trespassers might ride All-Terrain Vehicles (ATV) and motorcycles on the site areas with roads and ditches.

<u>Ballplaying trespassers</u>

Non-cancer illness – Figures 10 through 12 show that only PAHs exceed their comparison values in surface soils and sediments in the western part of the site where ballplayers might be exposed. We estimated doses for site trespassers aged 11 to 21 years old, exposed to onsite soils two times a week, 26 weeks a year (fewer than 52 due to frozen soil and snow coverage), for 10 years. For the exposure point concentration, we used the 95th percentile average of the PAH soil levels greater than 0.016 µg/L and less than 1.6 µg/L (shown as brown and red dots on Figure 10). Ballplaying trespassers who incidentally ingest surface soils are not likely to experience non-cancer illnesses from PAHs (Table C-10). Estimated doses are far below the chronic reference dose.

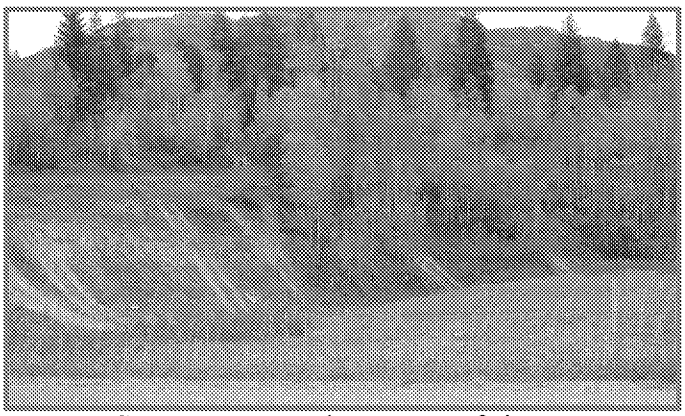
Cancer – The calculated increased cancer risks for ballplaying trespassers on this site are 1.1 in 10 million. This level is not considered a significant increase as it is less than 1 in 1 million (Table C-10).

<u>Motorcycle or ATV-riding trespassers</u>

Non-cancer illness – Figures 10 through 12 show that the chemicals exceeding their comparison values in surface soils and sediments near the plant and plant roads are primarily PAHs and fluoride. We estimated doses for site trespassers aged 11 to 21 years old, exposed to onsite soils two times a week, 26 weeks a year (fewer than 52 due to frozen soil and snow coverage), for 10 years. We calculated the 95[th] percentile average of the PAH soil levels greater than 1.6 μg/kg (shown as orange, yellow, and green dots on Figure 10) using ProUCL [EPA 2018j], to determine the exposure point concentration. We also used ProUCL to calculate exposure point concentrations for other surface soil chemicals above their comparison values.

Using average chemical values (exposure point concentrations) to calculate doses, we found vehicle-riding trespassers are not likely to experience non-cancer illnesses from incidentally ingesting PAHs, fluoride, arsenic, aluminum or dioxins in surface soil (Tables C-11 through C-16). Estimated doses are far below chemicals' chronic reference doses, proposed chronic reference doses, or minimal risk levels. Copper does not have a minimal risk level; and only one sample exceeded the comparison value.

Cancer – We calculated low increased cancer risks for vehicle-riding trespassers for PAHs, 2 to 3 in 100 thousand (Table C-11) and very low increased cancer risks for arsenic (Table C-13), 1 to 2 in 1 million.



DPHHS May 9, 2018 photo west of site showing many off-road ATV trails

We recommend against trespassing on the site, as some samples came from areas with concentrated contamination. Tests found the highest levels of contaminants in ditches leading to the percolation ponds, in the percolation ponds, and in former waste disposal areas (Figures 10 through 12). These contaminated areas likely have high concentrations of fine particles that might adhere to the ATV bodies or tires with mud .

Figure 6 shows the Northwest Percolation pond is near an open field on the west side of the site. Depending on the sport, if an errant ball lands in this percolation pond mud, players touching it might ingest contaminants via hand-to-mouth activities.

Recreationalists' exposures to onsite sediments

ATSDR staff noted community members were worried about children playing in Cedar Creek (David Dorian, December 12, 2017 email). To evaluate recreationalists' exposures, we assumed children might be exposed to Cedar Creek sediments on the site (as we currently have no offsite data) and fishermen might access seep ponds on the site from the Flathead River.

Non-cancer illness – Figure 13 shows the locations where PAHs exceed their comparison values in sediments. PAHS are a family of chlorinated hydrocarbon compounds with similar toxicological properties. ATSDR uses the Office of Environmental Health Hazard Assessments Potencies Equivalency Factors (Table C-4b) to determine one PAH Toxicity Equivalence (TEQ) value for each sample.

ATSDR evaluates sediments as if they were surface soils. Accordingly, the PHAST dose calculation method assumes a person will swallow between 50 and 200 mg of sediments daily, depending on age, weight, and exposure scenario (explained further in Appendix B). We modified the skin exposure portion of PHAST to include head, hands, forearms, lower legs, and feet for people who might be in the water. We evaluated exposures for persons ages 6 and older, twice weekly, 26 weeks a year, for 35 years. For the exposure point concentration, we used the 95th percentile average of the PAH soil levels that exceeded the comparison value. We found that recreationalists who incidentally ingest sediments are not likely to experience non-cancer illnesses from PAHs (Table C-17). Estimated doses are far below the chronic reference dose and are therefore not likely to cause illness.

Cancer – We calculated increased cancer risks for recreationalists on this site of 1.6 in 10 million (Table C-17). This is considered an insignificant increase as it is less than 1 in 1 million.

Current and future workers' exposures to onsite surface soils

CFAC is still near the beginning of the Superfund process path, at the Remedial Investigation (RI). While consultants are still testing samples to determine locations and levels of contaminants, the Draft Human Health Risk Assessment Work Plan reported the owner plans future commercial or industrial use for the site [EHS 2017]. Therefore, we did not evaluate future residential exposures. Recycling workers are present on the site now, and the future exposed population will likely be workers; based on the future land use scenario. To be conservative, we evaluated outdoor, construction-type workers' exposures to surface soil.

Non-cancer illness – Figures 10, 11, and 12 show where COPCs exceed comparison values (for residential exposures) in surface soil. We estimated doses for site workers older than 21, exposed to onsite soils 5 days a week, 26 weeks a year (due to frozen soil and snow coverage), for 35 years. Exposure values for outdoor workers assume they will incidentally ingest 330 mg of soil daily (a little less than what two average postage stamps weigh) from hand-to mouth activities.

Outdoor workers who incidentally ingest surface soils are not likely to experience non-cancer illnesses from PAHs, aluminum, fluoride, arsenic, copper, or dioxins (Tables C-18 and C-19). Estimated doses are far below the chronic Reference Doses or Minimum Risk Levels and are therefore not likely to cause illness.

Cancer – Our calculated increased cancer risks for outdoor workers are low for PAHs, an increased risk rounded to 4 in 100 thousand (Table C-19a). Our calculated increased cancer risk for arsenic rounded to 2 in 100 thousand (Table C-19a). The calculated increased cancer risks for outdoor workers for exposure to dioxins is 5.5 in 10 million (Table 19b). This is less than 1 in 1 million, which is not considered a significant increase.

Our dose calculations do not address health risks for people exposed mostly to soils in former waste disposal areas. We recommend current workers avoid contact with former waste disposal areas because chemical concentrations are likely highest there. We recommend remediation measures prevent future workers' exposures to areas with higher concentrations of contaminants. Sources of contamination can be removed or capped.

Past, current, and future workers' exposures to onsite groundwater

Former workers were not likely exposed to contaminated groundwater from the 235-foot onsite production wells as multiple tests failed to detect contamination in these wells [Roux 2018]. These production wells are not currently in use, and future site users will benefit from protections decided on during remediation, such as deed restrictions prohibiting use of contaminated groundwater.

Site Specific Limitation of Findings

We are unable to evaluate workers' past exposure levels because appropriate samples were not taken when Columbia Falls Aluminum Company site was in operation. Based on historical accounts, workers may have had emissions exposures at work and at home [Hanners 2018].

Community Health Concerns

We identified the following community health concerns from a community meeting, September 29, 2016; and from Community Action Group [CAG 2018] and Community Liaison Panel [CLP 2018] websites. We address community concerns in this section.

Questions about groundwater:

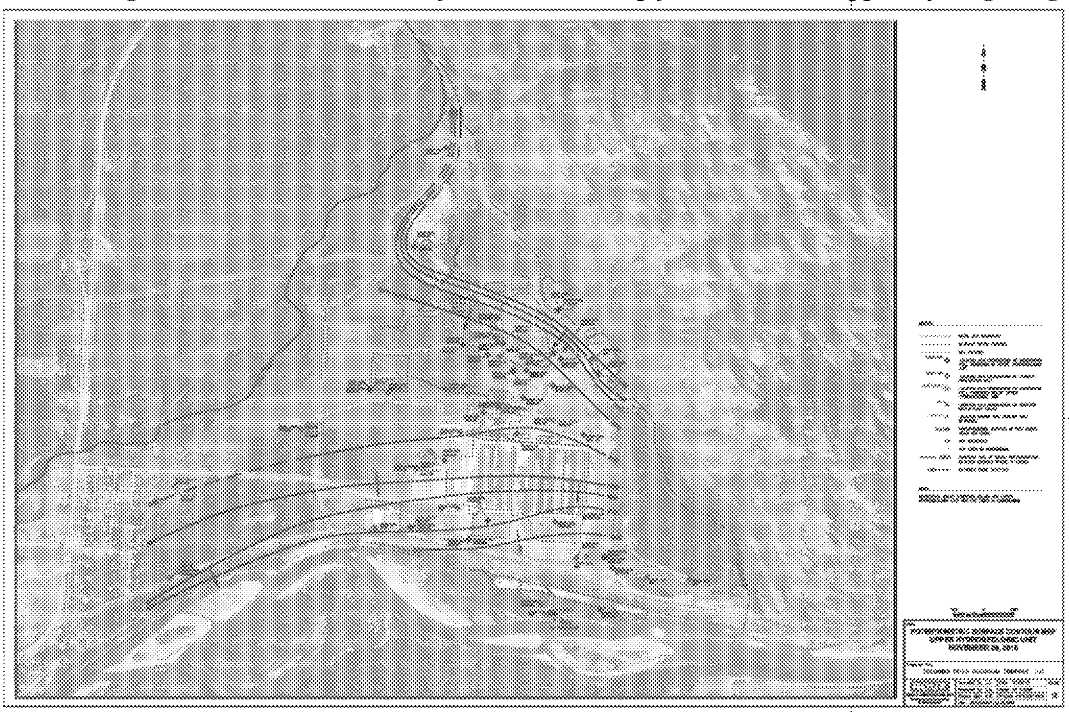
Q. Are wells and water infrastructure systems contaminated? Will they need to be upgraded or replaced, and could site contamination impair area water supplies over the long term?

A. The short answer is no. To understand what is happening with groundwater below the surface, hydrogeologists report the type and size of the material that comes to the surface when wells are drilled, in drilling logs. Hydrogeologists use the network of drilling logs to create a picture of what the underground sediment layers look like.

Drilling logs show two units of glacial sediments overlie non-water bearing bedrock at the site. The upper hydrogeologic unit is coarse-grained and easily transmits water. North to south, this unit varies in thickness from 50 to 150 feet [Roux 2017a]. The lower unit is made up of dense, poorly-sorted glacial till with beds of clays and silts that don't easily transmit groundwater. Together, the two glacially deposited sediment layers are 200 feet or greater, site-wide.

When consultants measure the elevations of groundwater in a well network they can connect (or interpolate) these elevations and determine what the water table surface looks like. Groundwater runs "downhill" along the water table. Figure 9 shows the upper hydrogeologic unit water table surface for November 29, 2016, also called a potentiometric surface contour map. Lines show equal groundwater elevations with arrows pointing in the direction of groundwater flow [Roux 2017a].

Figure 9. Potentiometric surface contour map for the CFAC upper hydrogeologic unit



[Roux 2017a]

Groundwater on the site flows southwest in the north, then south-southeast as it approaches the Flathead River. During Spring high flows, the Flathead River may recharge (contribute water to) groundwater. The clay layers in the lower hydrogeologic unit form a barrier. Groundwater that hits this barrier tends to flow on top of it: when it nears the Flathead River, it flows out in seeps. Hydrogeologists call this a perched aquifer.

Private well test results show contamination does not appear to be moving toward the private wells west of the site. Only two tests from 2013 showed cyanide above a residential comparison value that is *below* the drinking water standard. DPHHS recommends continuing private well testing to reassure people drinking this water that it is not contaminated, and it appears this testing has been on-going.

We mapped onsite groundwater test results above their comparison values on Figures 15, 16, 17, and 18. These test results show groundwater contamination is mainly in the center of the industrial portion of the property. Deed restrictions can be used to prevent people from using onsite groundwater for drinking water. Figure 14 shows that cyanide is the only contaminant in groundwater flowing into surface water at the seeps. The Flathead River is not a drinking water source, but surface water test results exceed Montana surface water cyanide human health standards. The test results for the samples taken in 2018 will allow us to have a better understanding of the water quality in the cut-off channel south of the site. These results will allow us to better understand whether levels are high enough to indicate a need to sample fish tissue that people might eat, and if so, for which contaminants.

Q. Does contaminated site runoff impact groundwater?

A. Within the contaminated areas on the site, runoff does impact groundwater. Rain and snow-melt can carry chemicals at the surface or buried in landfills into the groundwater. Roux (2017a, 2017b) compared soil test results with EPA Protection of Groundwater Risk-Based Soil Regional Screening Levels [EPA 2018f] for this reason.

Rain and snow-melt can also carry chemicals at the surface farther along the surface, and sometimes off the site. However, the former operations area is mostly surrounded by less contaminated areas which in turn are bordered by surface water bodies. Surface water runoff from the site could exit the site, without entering a surface water body, only along a portion of the southwestern boundary. We did not plot surface soil contamination near Aluminum City on Figures 10, 11, 12, and 13 because tests did not show soil contamination above comparison values in this area. Figure 10 has an inset with all soil sample locations and Roux took additional samples this summer (2018) to further delineate onsite contamination.

Q. Which contaminants have been identified in area water supplies and do those concentrations pose a risk to public health or the environment?

A. Testing has found traces of cyanide, fluoride, and manganese in offsite private drinking water wells. No offsite well test results were above enforceable drinking water standards [EPA 2018e, DEQ 2017]. Fluoride and manganese were not above their comparison values. We discuss the possible health risks for low levels of cyanide in drinking water in the Pathway Analysis and Health Evaluation Section.

Q. Could private water well testing letters explain what the laboratory results mean?

A. Yes. We (DPHHS) can work with the test-results letter-providers to better explain the private water well testing laboratory results.

Questions about surface water:

Q. What are the health risks for exposures to cyanide in groundwater seeps?

A. Two cyanide levels in groundwater seeps are above the drinking water standard of 200 µg/L (Figure 14). If people were to collect water from these seeps, there would be too much cyanide for drinking it daily. Critical effects (the lowest dose known to have adverse health effects) from animal studies include impairment of the male reproductive system. However, seep water is on the site, and currently no one is using seep water or surface water from other connected (Flathead River) or nearby water bodies (Cedar Creek or Cedar Creek Reservoir Overflow ditch) for drinking. At the request of DEQ we calculated a dermal dose, and found it far below the Minimal Risk Exposure

DEQ has a surface water quality standard for cyanide, 4 µg/L, for human health. Because water from the seep areas have cyanide levels above 4 µg/L (Figure 14), state regulations will likely require remediation plans to address these cyanide levels. It is important to remember that this is a very low level, equal to 4 parts per billion. If you have 7 people in a room, that equals 1 part per billion for the entire earth's population of 7 billion people.

Q. What are the potential health risks for kids playing in Cedar Creek?

A. Cyanide in surface water and PAHs in sediments are the only chemicals that testing found above health-based comparison values. Although it is not a drinking water source, test results did not exceed drinking water standards; however, remediation may address cyanide levels in Cedar Creek because three samples exceeded the DEQ 4 µg/L level for surface water human health protection.

We evaluated children's and adult's exposures to PAHs in sediments while swimming and playing. Our dose calculation method assumes children and adults will accidentally swallow 50 to 200 mg of sediment, each time they swim (Appendix B). We estimated exposure frequency could be twice a week, 26 weeks a year. We looked at age groups from 6 years to adult (Table C-17). We would not expect non-cancer health effects at the doses we estimated as they are below the cyanide reference dose. The cancer risks we estimated are not considered significant as they are less than 1 in 1 million.

Questions about onsite soil:

Q. Community members reported "In spite of 'no trespassing' signs near the site, people continue to access the area to play ballgames and ride motorcycles and ATVs." They asked what are the potential health risks for trespassers?

A. These concerns were reported several years ago. Based on what we saw on our site visit, there are many of outdoor workers on the site, working extended hours. And the entryway signage indicates the owner is serious about preventing trespassing.

We were aware of these pathway concerns and discussed them in the Pathways Analysis and Health Evaluation section. For the exposure scenarios we describe, we concluded ballplayers are unlikely to experience non-cancer or cancer health effects. Vehicle riders are unlikely to experience noncancer effects. Calculated increased cancer risks for vehicle-riding trespassers are low for PAHs with an increased risk of 2 to 3 in 100 thousand (Table C-11). Calculated increased cancer risks for arsenic are very low (Table C-13), at 1 to 2 in 1 million.

We recommend against trespassing on the site, as some samples for our exposure point concentrations came from areas with elevated contamination levels. Tests showed the highest levels of contaminants in ditches leading to the percolation ponds, in percolation ponds, and in former process and waste disposal areas. These areas likely have fine particles (mud) that might adhere to ATVs and motorcycles and be transported off the site. The Northwest Percolation pond is near an open field on the west side of the site. Depending on what type of sports might be played there, if a ball landed in the pond, mud on that ball might be ingested from hand-to-mouth activities.

Q. What effects have the on-going recycling and disposal activities on the site had on the surrounding areas? Did transportation of asbestos and other hazardous materials through the community create air quality issues?

A. Transportation of asbestos and other hazardous materials followed state and federal regulations which require shipping in sealed railroad containers, or in covered or sealed trucks. These regulations are set to prevent airborne dust (email from Richard Sloane, DEQ Project Manager for the CFAC site 3/1/2018).

Questions about offsite contamination:
Q. What were the aluminum production byproducts? What was in air emissions, and specifically what could residents have been exposed to in air?

A. **What were the aluminum production byproducts?** CFAC solid wastes included spent potliners. Potliners were disposed of in two onsite, unlined landfills in the 1980s. All spent potliners from the Columbia Falls smelter were shipped out of state by 1985 when ARCO sold the plant. Wet, and later, dry scrubbers cleared chemicals from emissions particles exiting the potrooms. Workers cleaned out chemicals that accumulated in these scrubbers with water and routed this water to percolation ponds north and northeast of the plant. Percolation pond and spent potliner materials remain on the site and contain PAHs, fluoride, cyanide, arsenic, and metals above comparison values for residential land use [Hanners 2018, chapter 34, page 18 explains wastes from early production processes and chapter 37 page 7 explains wastes from later production processes].

What was in air emissions? DEQ's latest air permit for CFAC contained requirements and conditions for contaminants in vegetation animals use for food (from ambient air quality standards[1]), ambient air visibility (40% and 20% opacity), airborne particulate matter (20% Fugitive Opacity), visible emissions (10% opacity), sulfur oxide (1 lb per MMBtu[2] fired and 50 gr per 100 cubic feet), aluminum MACT[3] (fluoride and PAHS), and fluoride (2.6 pounds per ton aluminum produced). Fluorides can occur as hydrogen fluoride (HF; toxic to vegetation) or perfluorocarbons (strong absorbers of infrared radiation, and therefore powerful greenhouse gases). Particulate matter included PAHs, various other carbon compounds, and sodium- and aluminum-fluorides. DEQ determined the plant mostly met these conditions [DEQ 2013].

After the 4th and 5th potlines started in 1968, CFAC plant emissions were reportedly much higher than they had previously been. When air emissions standards were issued in the early 1970s, the plant was not able to meet them. ARCO merged with Anaconda Company in 1977. ARCO and Anaconda spent more than 42 million dollars upgrading the plant with potlines that used less energy and were easier to load with ore. They also could be hooked to dry scrubbers which captured more of the fluoride emissions. The plant met fluoride emissions standards in 1980 [Hanners 2018].

Columbia Falls has had other significant air pollution sources in the past. Montana banned open burning on May 1, 1970. Prior to that time, several timber facilities burned sawdust in cone-shaped "tee-pee burners" and residents and landfills burned household trash. Some residents reported materials were burned at the landfill even after open-burning was banned in 1970. Timber facilities producing plywood and particle-board also emitted large quantities of formaldehyde and ammonia until a solution was found in 2008. Gravel applied to icy roads were sources of airborne dust because before 1987 two-thirds of Columbia Falls Roads were unpaved [Hanners 2018].

What do other studies say about what residents could have been exposed to in air?
We found a literature review which summarized scientific studies describing the health risks to communities near aluminum reduction plants [Martin and Larivière 2014]. These researchers found the following:

- medium risks for exposure to small particulate matter ($PM_{2.5}$) and sulfur dioxide,
- low to medium risks for PAH exposures (for Søderberg process reduction *which was used at CFAC until the mid-1970s*), and
- low risks for exposures to fluorides, noise, and larger particulate matter (PM_{10}).

We discuss these findings in order of relative risk.

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[1] Foliage as measured by dry weight: 40 mg/kg average growing season, 60 mg/kg for two consecutive months, and 80 mg/kg once in two consecutive months. Ambient air action levels include (1) All sampling to determine compliance with these action levels shall be conducted in locations and during time periods consistent with protecting vegetation of the type and in areas covered by this chapter. (2) Gaseous fluorides in the ambient air calculated as hydrogen fluoride standard conditions shall not exceed: (a) 2.9 μg/m3 = average for any nonoverlapping twenty-four consecutive hours; (b) 1.7 μg/m3 = average for any seven consecutive days; (c) 0.84 μg/m3 = average for any thirty consecutive days; (d) 0.5 μg/m3 = average for the growing season.
[2] One million British Thermal Units, a measure of energy content in fuel.
[3] Maximum Achievable Control Technology, a level of control introduced by Title III, 1990, Clean Air Act Amendments.

Medium risks: $PM_{2.5}$ — Scientists abbreviate sizes for particle matter with diameters less than 10 microns and 2.5 microns as PM_{10} and $PM_{2.5}$, respectively. Exposure to small particulate matter has been linked to cough and wheeze, onset and exacerbation of asthma in adults and children, hospitalizations for respiratory and cardiovascular diseases, increased death rates in vulnerable groups (the elderly, babies 7 to 28 days old, and low birth weight babies [Gruzieva et al. 2010]). Studies show adverse cardiovascular outcomes more strongly associated with the smallest particles, $PM_{2.5}$ [Dennekamp et al. 2010, Lipsett et al. 2011, Abraham and Baird, 2012].

Medium risks: Sulfur dioxide — Studies measuring offsite sulfur dioxide levels near aluminum reduction plants found some hourly averages to be in the range of 200 parts per billion. This level is known to produce bronchoconstriction in persons with asthma [Lewin et al. 2013, Johns et al. 2010].

Low to medium risks: PAHs — Studies predicted excess lung cancers related to PAH exposure in nearby communities based on the dose-response relationships seen in smelter employees [Gibbs 1997]. A quantitative risk assessment found a correlation between PAH exposure and lung cancer in women [Vyskocil et al. 2004]. A study found an excess of lung cancer in women in the most highly exposed district of a Canadian town with an aluminum reduction plant [Bouchard 2000].

Low risks: Fluorides — As was found with aluminum reduction plant workers developing potroom asthma [Abramson et al. 2010], a study of children living near an aluminum reduction plant in upstate New York showed respiratory obstruction due to inhalation of plant emissions could be correlated with increased urinary fluoride [Ernst et al 1986].

Low risks: Noise —The contribution of aluminum production operations to community sound levels are well below levels causing hearing loss [Martin and Larivière 2014].

Q. What were historical impacts from CFAC facility operations on local air quality?

A. From 1955 to the early 1970s, CFAC operated with pollution controls limited by the technology of the times, and without air emissions permits. “The Bonneville Power Administration’s (BPA) 1975 final environmental impact statement for direct-service industry power sales options provided figures for annual atmospheric emissions by the 10 aluminum smelters in the Pacific Northwest” including the Columbia Falls Aluminum Co. in Columbia Falls, Montana [Hanners 2018]. BPA’s estimate for CFAC annual emissions included 837 tons of particulates, 456 tons of fluoride, 624 tons of hydrocarbons, and 1,850 tons of sulfur oxides [Little 1978]. In the late 1960s and early 1970s, farmers, plant nursery operators, and National Park and National Forest personnel noted blighted vegetation related to fluoride emissions. Ranchers and hunters noted animals with worn teeth and lameness attributed to feeding on fluoride-affected plants [Hanners 2018].

After national air quality standards were issued in the early 1970s, the facility operated under a variance with DEQ because the available technology did not allow operators to meet air quality standards [Hanners 2018]. We note other air pollution sources in the "What was in air emissions?" question. The past impacts of air emissions on the public would have varied with wind direction and windspeed. Air quality information is available for a few properties for limited amounts of time [Montana Department of Health and Environmental Sciences 1975].

Q. What risks are associated with living in the area and what would minimize potential contact with site contamination?

A. Remedial investigations released in 2017 have not sampled offsite soil, sediments, surface water, or fish; making assessment of recent or current offsite exposures difficult [Roux 2017a, 2017b].

Test results for samples taken on the site's perimeter in 2018 will allow us to better evaluate the likelihood of off-site contamination. Emissions of site chemicals DEQ regulated included fluorite as hydrogen fluorite, perfluorocarbons, sodium- and aluminum fluorides; along with PAHs and other particulates [DEQ 1999]. Chemicals emitted to air may have settled onto offsite soil, sediments, and surface water.

Q. Is fluoride inhalation linked to mental health issues?

A. We found reports of neurological but not mental health effects. Central nervous system effects from occupational exposure to fluoride (studied in potroom workers exposed for more than 5 years) include deficits to memory, attention, hearing and visual retention, and manual dexterity [Yazdi et. al 2011]. Studies of persons living in areas with fluoride exposures via water (causing endemic fluoride poisoning) found central nervous system effects including poor memory, fatigue, headaches, excessive thirst, and excessive urination [Doull et al 2006, Sharma et al. 2009].

Q. Is fluoride inhalation linked to autoimmune issues?

A. We found reports of immune but not auto-immune health effects. One animal study found excessive fluoride administered in food induces thyroid dysfunction [Wang et al, 2009]. The thyroid secretes hormones, which influence the immune system and metabolism. The ATSDR toxicological profile for fluorides, hydrogen fluoride, and fluorine did not evaluate autoimmune response as an exposure outcome and did not cite immune responses in humans [ATSDR 2003].

Q. Could atmospheric thermal inversions have resulted in greater exposures than were assumed by state air permitting?

A. Thermal inversion conditions trap cold valley air beneath more regional warm air fronts, preventing mixing and movement of the trapped air. Inversions could have increased the levels of emissions people breathed.

The addition of the 3rd potline in 1965, and the 4th and 5th potlines in 1968 would likely have more than doubled plant emissions, relative to what was released during the first nine years of plant operations with 2 potlines. Tests conducted by Anaconda and released during the discovery phase of a class action lawsuit indicated the plant fluoride emissions were 10,000 pounds per day during the late 1960s [Hanners 2018].

State air permitting for fluoride did not begin until June 30, 1973; the plant was unable to meet these standards until 1980. In 1978, plant improvements reduced fluoride emissions to 4,000 pounds per day. In 1980 fluoride emissions were down to 738 lbs/day, less than the Montana state fluoride limit of 864 lbs/day [Hanners 2018].

Other historical sources of air pollution in Flathead Valley included timber plants, open-burning, and dirt roads. State regulations banned open burning in 1970. Open waste burners included timber processers, private citizens, and landfills. Paving the dirt roads of Columbia Falls took many years to accomplish. Plum Creek fiberboard plant met the state formaldehyde emissions standard in 2008 [Hanners 2018].

Q. People would like to have educational materials about site conditions.

A. We encourage people to ask us questions that this report does not answer. Additional information is available on the internet:

- Summaries and data are available on EPA's CFAC site: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.docdata&id=0800392 [EPA 2018h].
- The Community Involvement Plan is available at http://flatheadbeacon.com/wp-content/uploads/2017/03/CIP-CFAC-2017draft.pdf [EPA 2018i]. EPA's Community Involvement Plan lists government contacts, and pages 12, 13, and 14 list many of the Community Health Concerns we are discussing in this section [EPA 2018i].
- Extensive background and current information, in plain language, and site documents for the CFAC site cleanup are available on the Columbia Falls Aluminum Company Project Page at http://www.cfacproject.com/. This website contains project updates and site photographs for readers interested in the progress of the demolition or the Superfund projects going on at the site. Community Liaison Panel minutes for 2015 through 2017 are linked on the Community Outreach tab of this website.
- The Community Liaison Panel minutes from this website are also a source of the Community Health Concerns we are discussing in this section. Some of the Community Liaison Panel minutes are also available on the City of Columbia Falls Montana webpage at https://cityofcolumbiafalls.org/cfac-liaison-panel.
- DEQ has a timeline that is updated monthly with the amount of hazardous waste removed from the site at http://www.deq.mt.gov/dir/cfac.mcpx.
- Calbag is recycling much of the material they are removing from the site and the total weight of the materials they have removed is included at http://www.cfacproject.com/communityoutreach/cfac-larger-brochure-dec-2017/.

- Calbag company information is available at http://www.calbag.com/.
- Information on Roux, CFAC's contractor, is available at http://www.rouxinc.com/.
- Historical information on CFAC is available at http://montana-aluminum.com/.
- Occupational studies are available on-line. The reader can find the information included in this report by typing the author names and article titles listed in the references into their browser.

Q. What is the prevailing wind direction? How does this link to emissions information?

A. From January through July, and in November, the prevailing winds are from the south, with next most-prevalent winds from the north. From August through October, prevailing winds are from the north, with next most-prevalent winds from the south. Locally, these wind directions correspond with the north-south alignments of Teakettle and Columbia mountains [USDOA 2018]. These would have been the primary emissions directions.

Q. What are the potential migration pathways for site contamination that could have broader watershed impacts, possibly affecting wildlife, water supplies, and the general health of area communities?

A. Based on the information we have now, water supplies are not a completed pathway for people; meaning migration of potentially contaminated groundwater and surface water offsite, where they might be used for human consumption.

- Groundwater — Based on onsite monitoring well and offsite private well tests, contaminated groundwater is moving south and not toward residences. Groundwater sampled from residents' private wells has not exceeded state and federal drinking water standards. One well showed cyanide at roughly half the drinking water standard in 2013, but Weston's report revealed the sample was improperly taken.
- Surface Water — Cyanide values at seeps near the Flathead River did have elevated cyanide above state drinking water standards. DEQ reports that there are no surface water intakes for public water supplies on the portion of the Flathead River downstream from the site. Test results for surface water samples taken in 2018 in the channel cutoff south of the site will allow us to better evaluate the potential human health effects of cyanide in the Flathead River.

The lack of offsite data limits our ability to answer questions about contaminants that might migrate offsite and affect the watershed and wildlife.

- Surface Water — Based on comparison of onsite surface water test results with state and federal standards, Cedar Creek and the seep springs exceed the 4 μg/L cyanide state surface water standard, these might contribute to surface water offsite (Figure 14). Surface water testing in the Flathead River and Cedar Creek would allow determination of the impact of onsite surface water cyanide to offsite surface water cyanide levels. Remediation requirements could address cyanide levels above state standards.

General health of the area communities – Some residents may have inhaled plant emissions between 1955 and 2009. Exposed community members' health effects might differ based on their length and level of exposure and the chemicals they were exposed to. The highest levels of emissions likely occurred after 1968 when the 4th and 5th potlines were added, and before 1980 when the Anaconda Company finished upgrading the plant's production and emissions systems (Appendix E).

Nearby residents' inhalation levels would have varied based on wind direction, settling characteristics of emissions, and proximity to the plant. Between 1968 and 1977,

- cows 4 miles south of the site reportedly developed health problems[4],
- nursery owners and gardeners reported tree deaths and other adverse impacts to plant growth, and
- National Park and National Forest staff measured elevated levels of fluoride on trees' leaves and needles [Hanners 2018].

CFAC workers could have been exposed at work and at home. Their exposure levels could have decreased over time, as required personal safety equipment became increasingly more protective and emissions were better controlled [Hanners 2018]. We discuss health effects of fluoride exposures in Appendix D. Emissions of other site chemicals DEQ regulated included sulfur oxides, PAHs and particulates [DEQ 2013]. Chemicals emitted to air may have settled onto offsite soil, sediments, and surface water.

Q. Could exposures to site chemicals be linked to specific diseases? Community members asked about Lupus, Carcinoid Tumors, Hashimoto's Disease, Sjogren's Syndrome, Scleroderma/Raynaud's Syndrome (dual diagnosis), birth defects, and cancers.

A. We address specific disease concerns in Appendix E.

Conclusions

1. Workers or trespassers touching onsite surface soil are the most likely to be exposed to site contaminants. They might accidentally swallow contaminated soil they get on their hands. We estimated what these amounts might be and found non-cancer illnesses are unlikely and increased cancer risks are low. Our calculations do not address persons who would primarily contact waste disposal or other highly contaminated areas.

2. We were unable to estimate exposure levels for residents contacting soil in their yards or in offsite sediments as consultants have not tested these offsite media.

[4] Fluorosis is a chronic disease caused by the continued ingestion of small but toxic amounts of fluorine in forage plants. Occurrence of dental lesions and joint and bone abnormalities depend on the age of the cow at the time of exposure and the level of fluoride ingestion [Ulemale et al., 2010]. While joint affects are seen first, bones become shorter, thicker, and more brittle later. Degenerative changes are seen in the kidney, liver, adrenal glands, heart muscle, and central nervous system. Bone marrow changes can lead to aplastic anemia.

3. Contaminated onsite groundwater should not be used as a drinking water source, and we did not identify anyone who drank contaminated groundwater on the site. Past testing of the production wells located east of the area of groundwater plume did not find contamination. When the plant buildings were dismantled, power to these production wells was cut off.

4. Since 2013, private well testing has not found site-related contamination, and we are unsure of the potential for health effects from the low levels of cyanide measured in 2013 testing. Testing in September 2013 found cyanide in two private wells; at levels less than the drinking water standard. Follow-up testing by a different company did not confirm these cyanide levels. Incomplete development of the male reproductive system was the health effect seen in a research animal study at the lowest cyanide exposure level, known as the critical effect level. Because the cyanide levels in these wells were far below those causing health effects in animals, and we don't know if or for how long people may have been exposed due to the lack of identification of cyanide in confirmation sampling; it is difficult to say if adverse health effects might be expected.

5. Tests show surface water in Cedar Creek and the Flathead River contains cyanide and sediments contain PAHs. Surface water near the site is not used for drinking. People's exposures to contaminants in surface water and sediments may be indirect.

6. Although we are unable to evaluate former workers' exposure risks, their health risks would likely have varied based on the area of the plant they worked in, when they worked there, and how long they worked there. Occupational studies show workers in the early 1950s and 1960s may have been exposed to higher levels of chemicals than later workers. In general, early process equipment emitted more gases and particulates and there were fewer requirements for personal protective equipment then. Workers in different parts of the plant would have been exposed to different chemicals and at different levels. More years of work would have meant longer periods for exposure

7. Vapor intrusion does not appear to be a potential exposure pathway. Our screening calculation showed a future unventilated building constructed above shallow groundwater with 0.28 µg/L 1,2-dichloroethane is not likely to accumulate vapors above the comparison value for indoor air. Most soil and groundwater testing did not find volatile chemicals, and this was the highest volatile chemical level measured.

Recommendations

Recommendations corresponding to our first four numbered conclusion include —

1. Avoiding or preventing contact with areas of elevated chemical concentration such as former production and waste disposal areas through use of personal protective equipment. People at risk now and in the future include: trespassers, recycling workers, and outdoor workers.

2. Testing offsite yard soil and sediments for chemicals that were found in onsite soil and sediments (this recommendation may change based on tests result for 2018 site perimeter samples).

3. Prohibiting new onsite drinking water wells that might contact contaminated groundwater.

4. Continued testing of residential wells near the site.

Our recommendations may change following community input or evaluation of new environmental sampling data.

Public Health Action Plan

Actions Undertaken

1. Since 2013, contractors for the EPA and CFAC have sampled 17 nearby private wells. Tests found no contaminants above drinking water standards.

2. EPA added this site to the National Priorities List on September 29, 2016.

3. Roux, the owner's consultant, conducted environmental sampling to characterize the site. They list test results for 610 separate soil and sediment samples and 240 groundwater samples from 64 monitoring wells and 100 surface water samples. They selected these sample locations with oversight and review by EPA and DEQ.

4. Montana DPHHS staff visited the site on May 9, 2018. This site visit allowed better exposure pathway assessment. We saw many workers on the site, afterhours, which should inhibit peoples' ability to trespass. We also saw the site was posted for night-vision camera use.

5. In 2018, Roux took additional samples. Phase II activities included

    - taking 52 soil samples to better delineate areas of surface contamination.
    - installing and sampling 8 new monitoring wells to better delineate groundwater contamination.
    - installing pressure transducers in 6 monitoring wells to continually track groundwater level changes, to provide a baseline for groundwater level measurements taken across the monitoring well network during high and low water periods.
    - sampling roughly 70 new and existing monitoring wells for the parameters described in the Environmental Data section during high and

low water times; and adding tests for dioxins and furan to the analyses for the monitoring wells downgradient of the rectifier yard.
- sampling 59 surface water locations during high and low water times (with exception of the areas already sampled during low water)
- sampling 59 sediment and sediment porewater locations.

Actions Planned

1. Phase II of the Remedial Investigation and Feasibility Study included more sampling to provide background contamination levels of site-related contaminants. Tests results will be available in 2019. The current owner's consultant will also finalize the Baseline Ecological and Human Health Risk Assessment Work Plans based on EPA and Montana DEQ comments.

2. Montana DPHHS will review new data and comment on the health implications of new test results.

3. Montana DPHHS staff will hold an open-house style public meeting for the community near the site to gather community comments about this report and to gather additional health concerns. Montana DPHHS staff will address these comments and concerns in the final release of this report.

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The Montana DPHHS prepared this Health Consultation for the Columbia Falls Aluminum Company site under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry. We prepared it in accordance with approved agency methods, policies, and procedures at the time of publication. ATSDR completed an editorial review.

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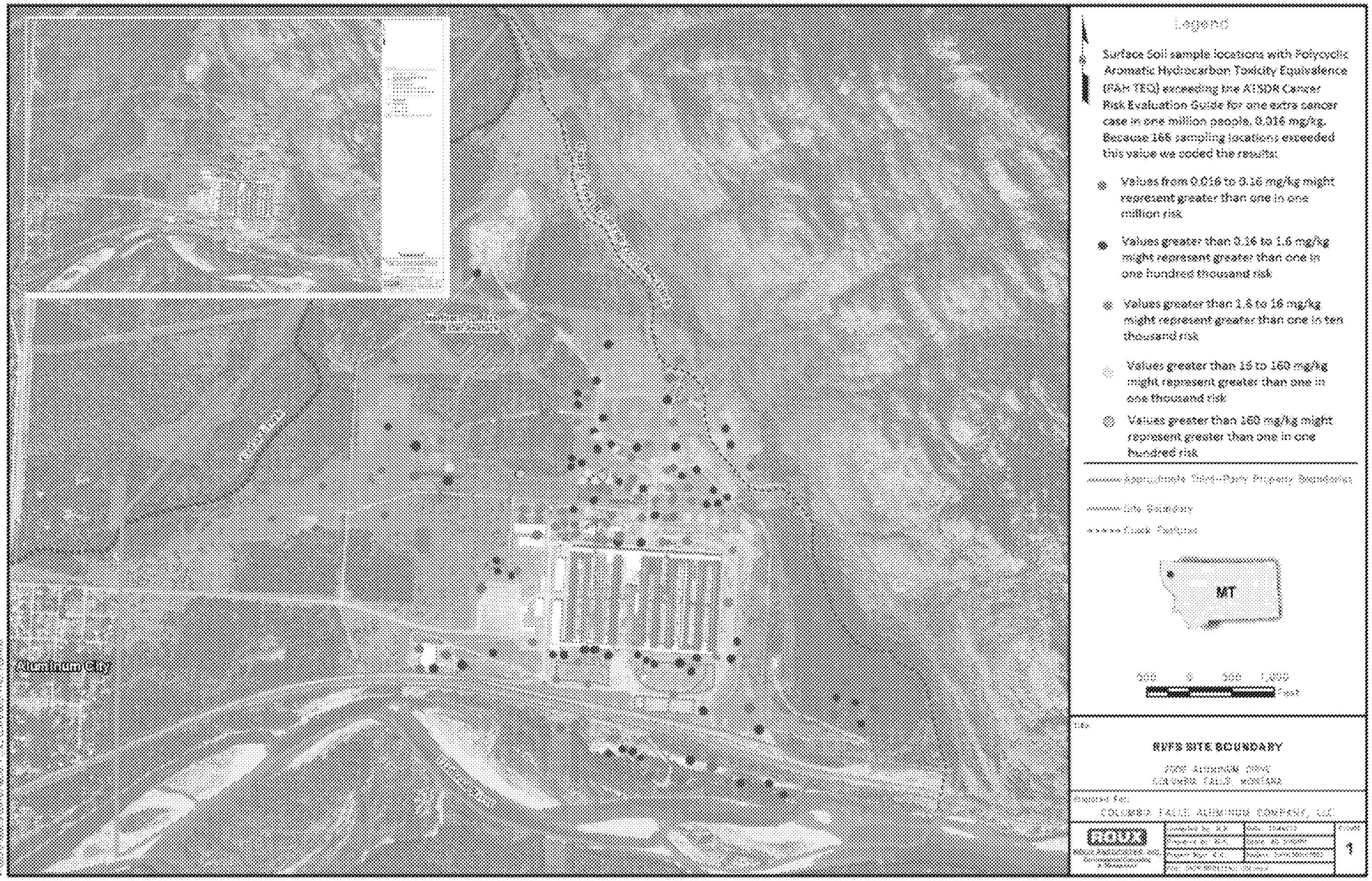
Appendices,

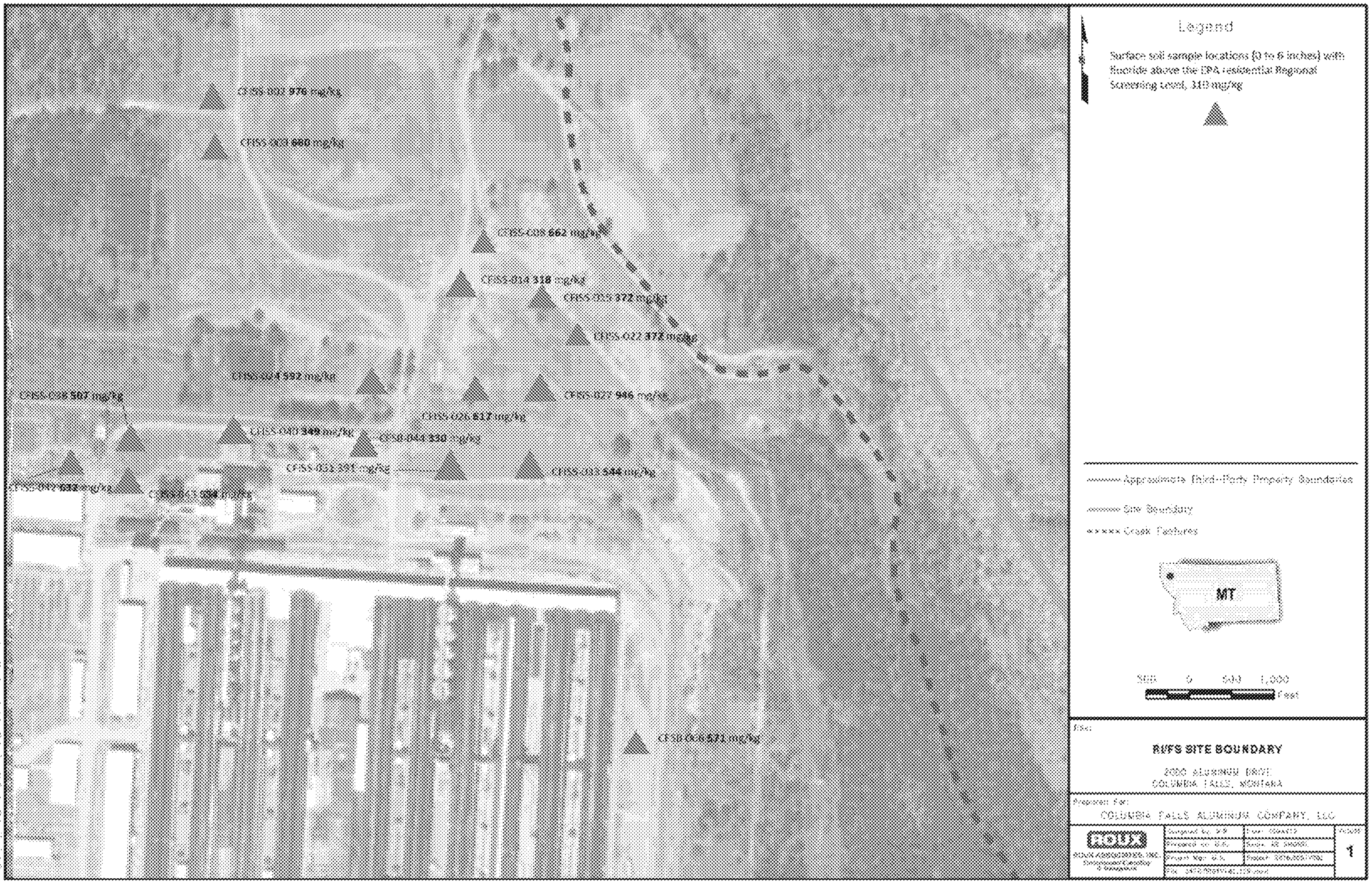
Appendix A. Figures

Figure 10. Columbia Falls Anaconda Company surface soil (0 to 6 inches) locations exceeding the PAH comparison values



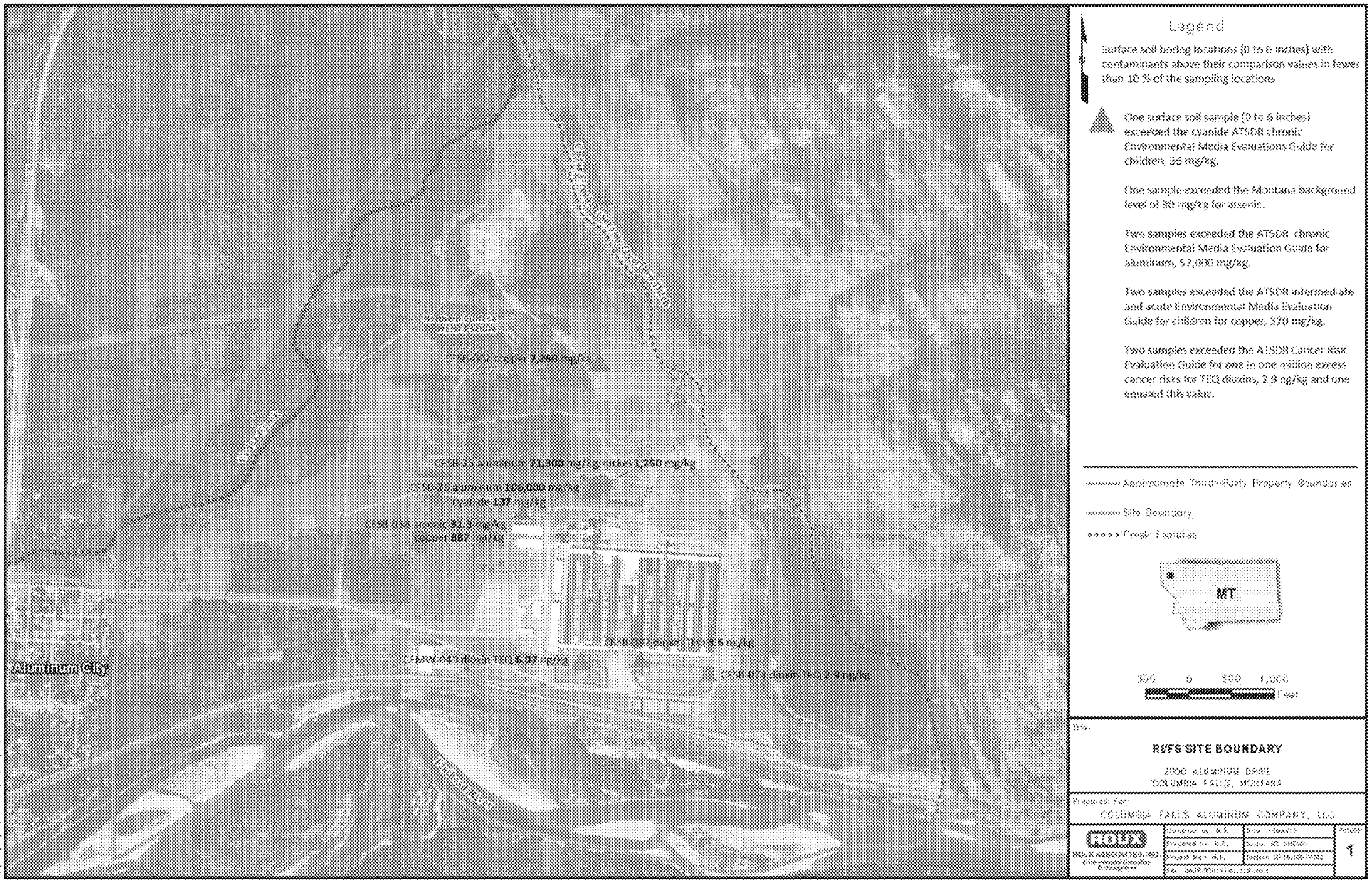
[Roux 17a data]

Figure 11. Columbia Falls Anaconda Company surface soil samples (0 to 6 inches) that exceed the fluoride comparison values



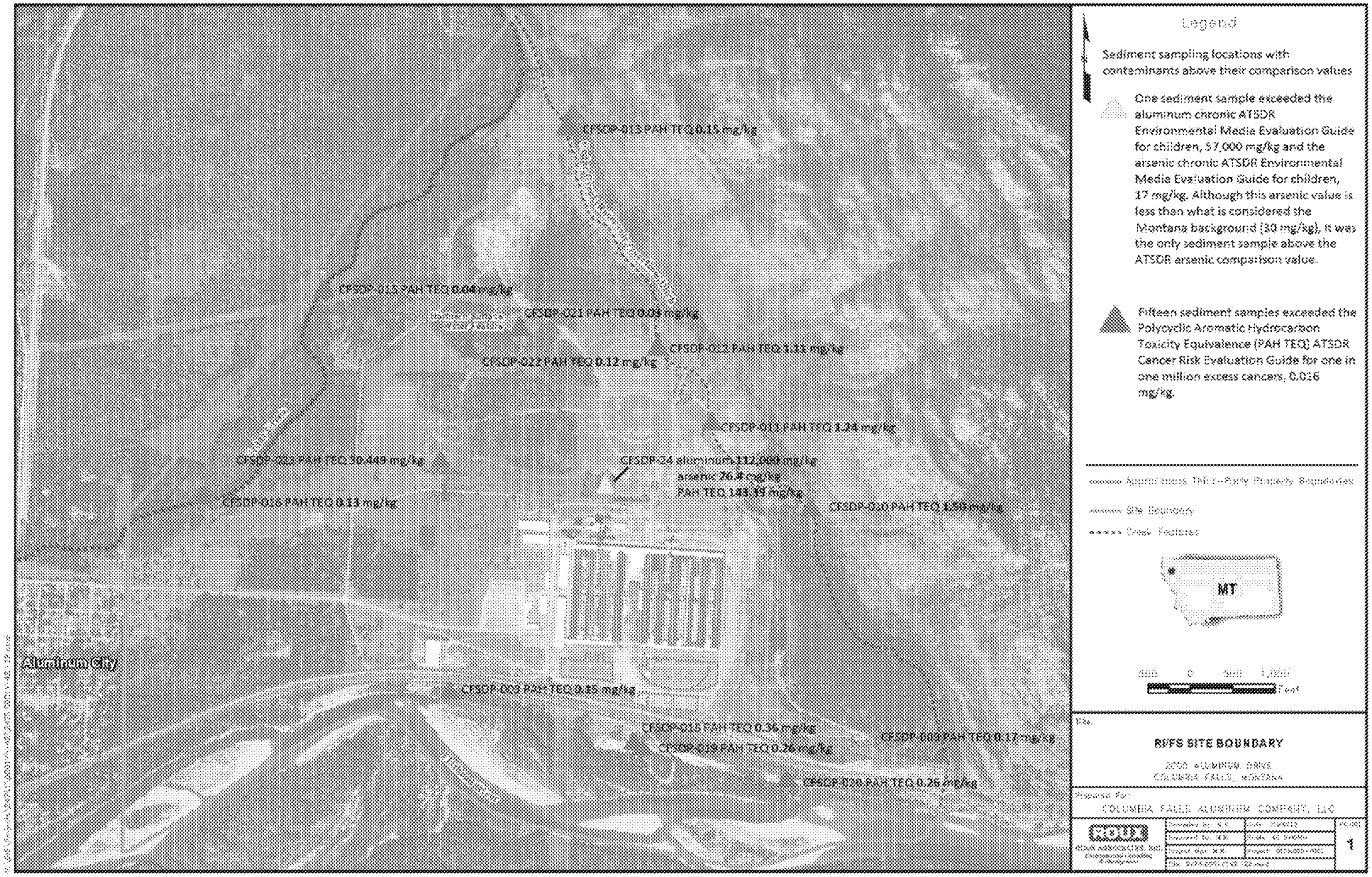
[Roux 17a data]

Figure 12. Columbia Falls Anaconda Company surface soil samples (0 to 6 inches) that exceeded COPC CVs



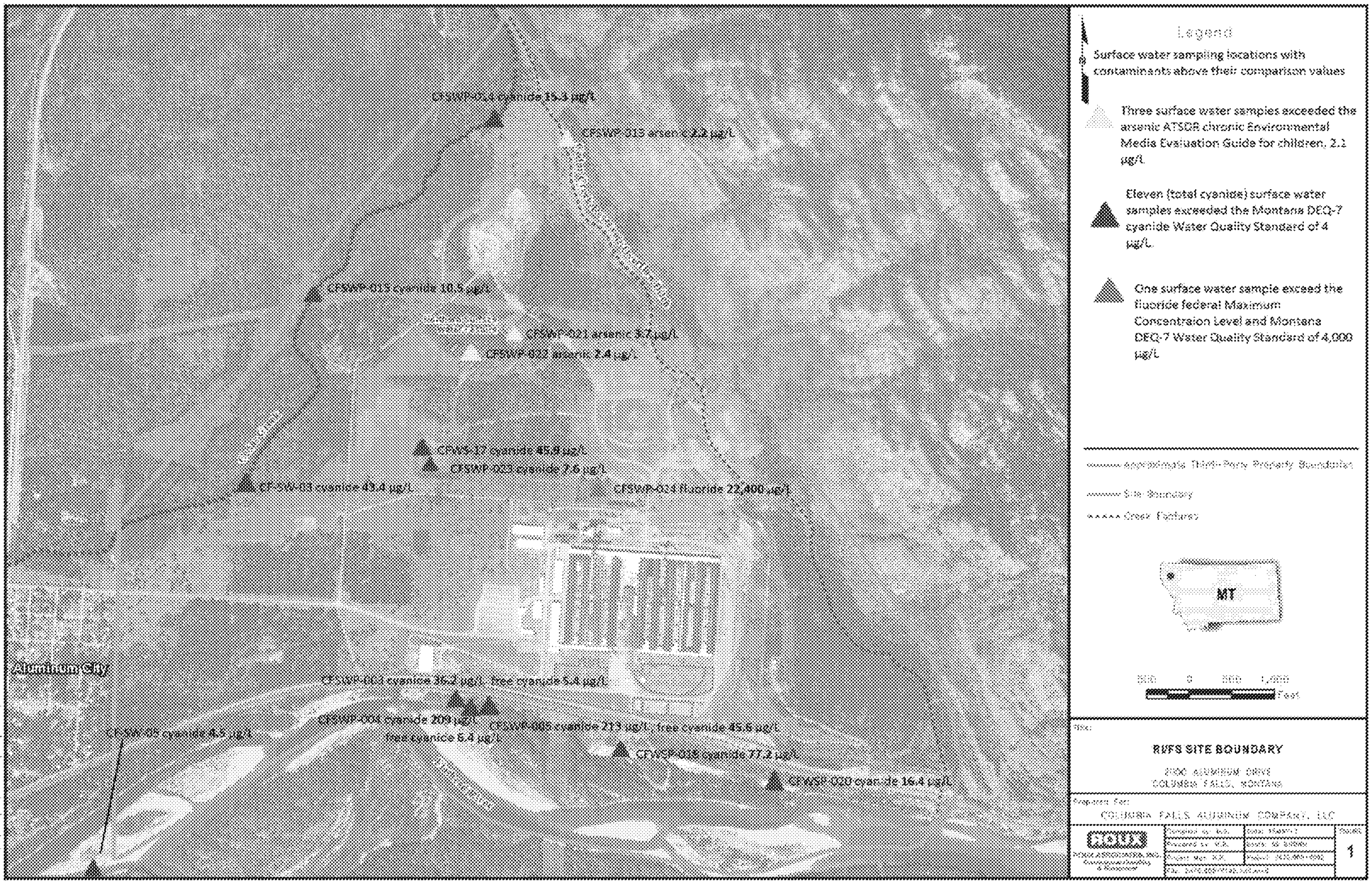
[Roux 17a]

Figure 13. Columbia Falls Anaconda Company sediment samples (0 to 6 inches) that exceeded COPC CVs



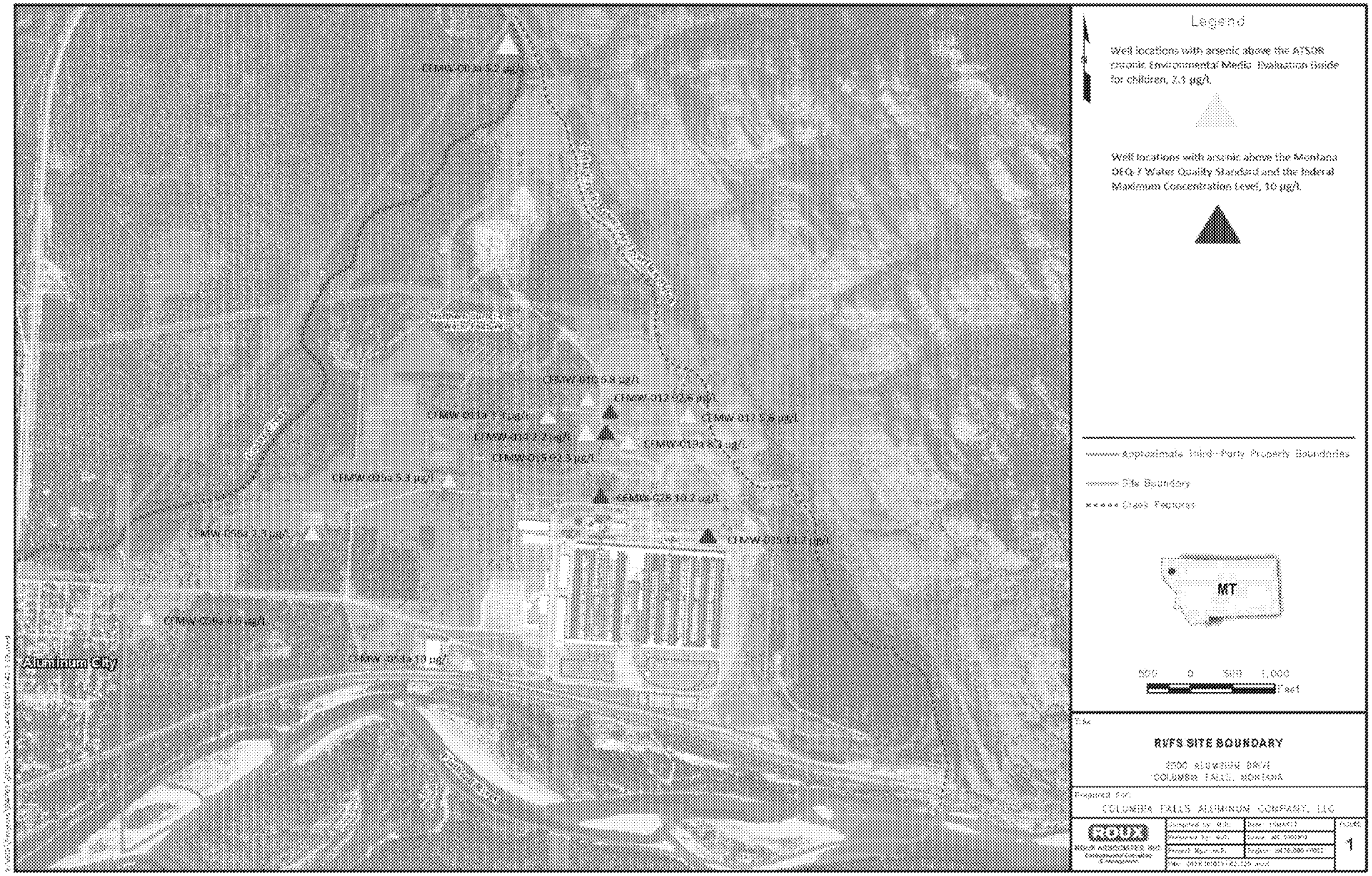
[Roux 17a]

Figure 14. Columbia Falls Anaconda Company surface water samples that exceeded COPC CVs



[Roux 17b]

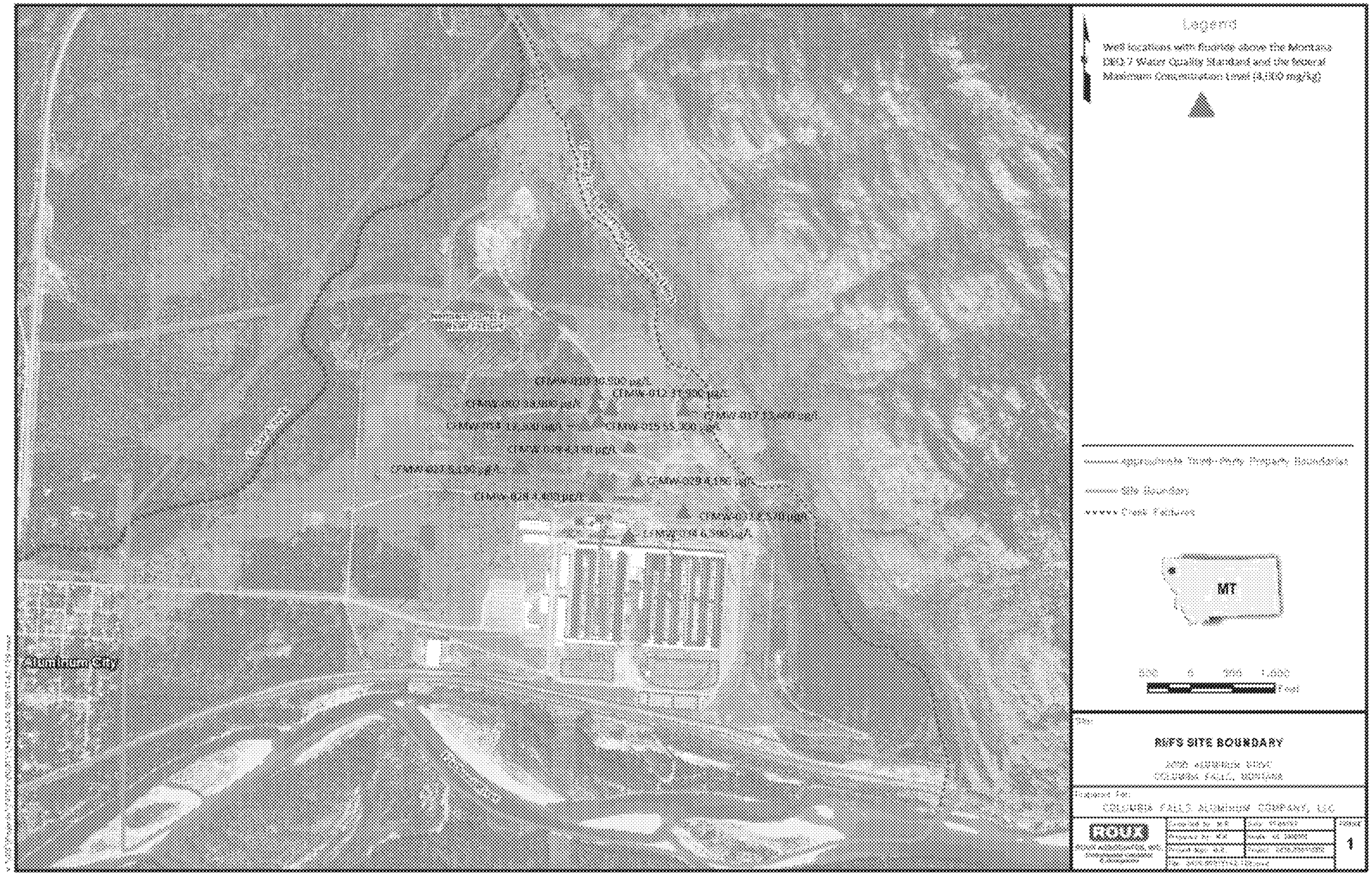
Figure 15. Columbia Falls Anaconda Company groundwater samples that exceeded the arsenic drinking water standard and CV



***[Roux 17b*]**

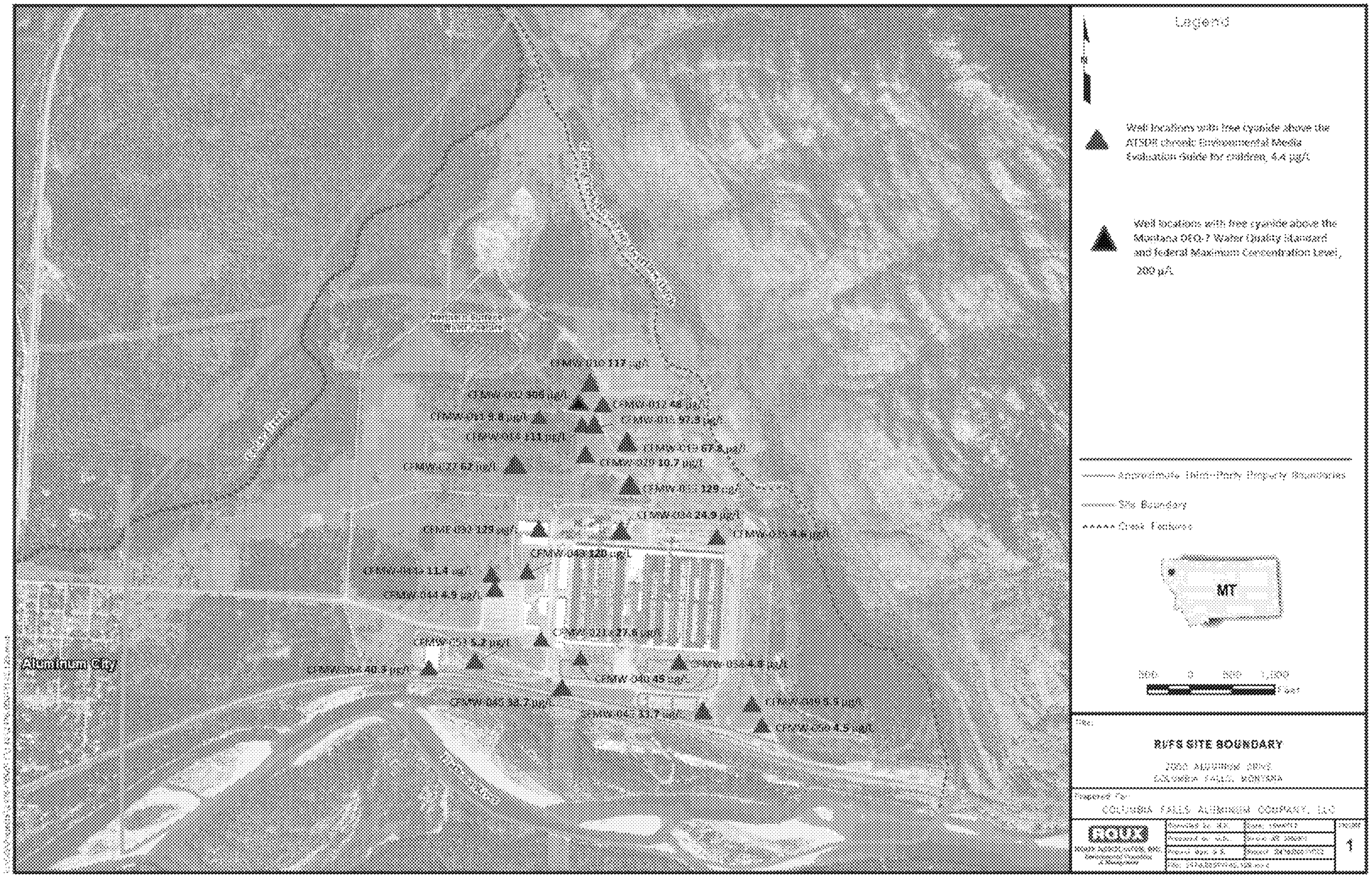
[PAGE]

Figure 16. Columbia Falls Anaconda Company groundwater samples that exceeded the fluoride drinking water standard



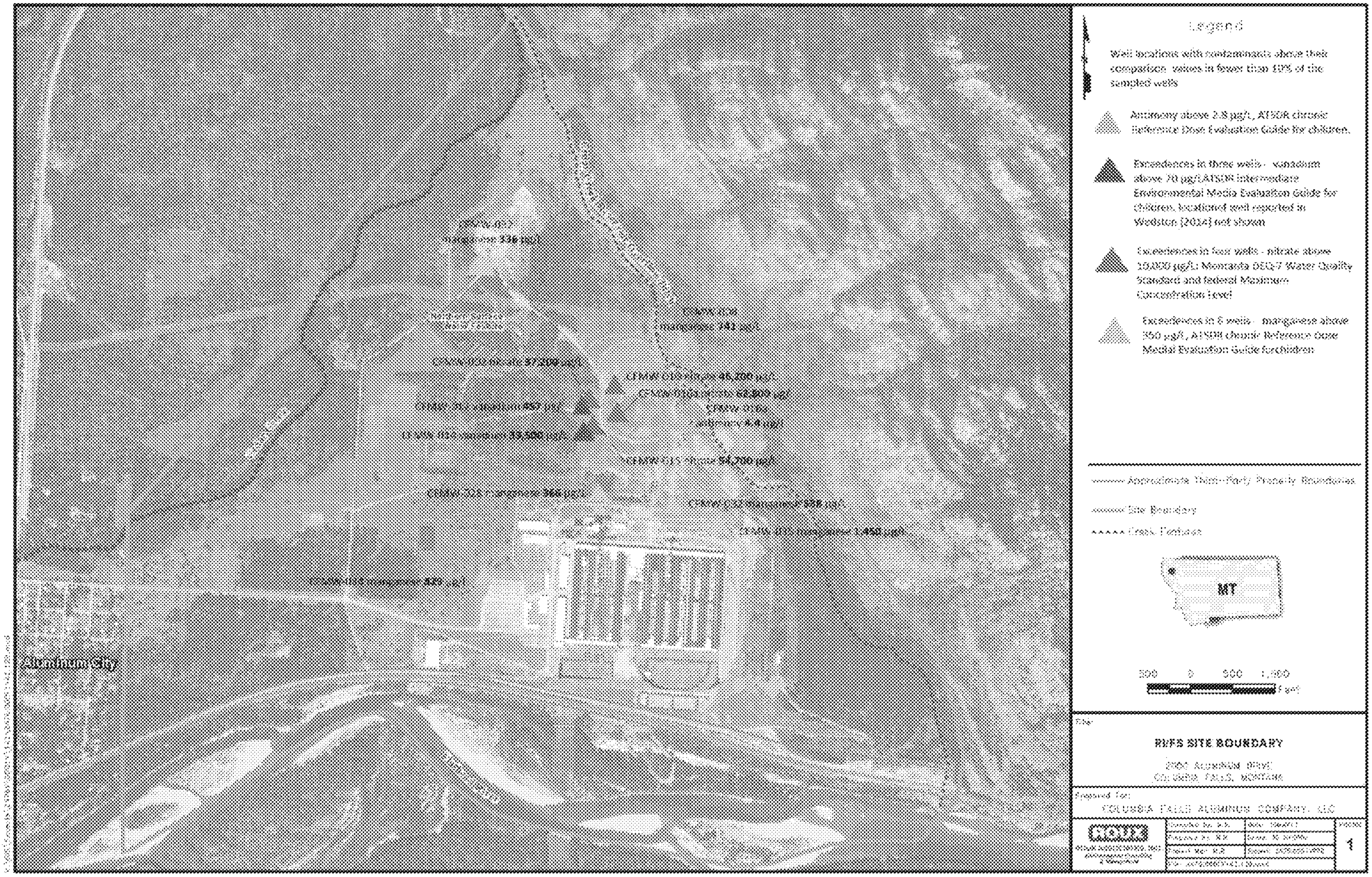
***[Roux 17b*]**

Figure 17. Columbia Falls Anaconda Company groundwater samples that exceeded the cyanide CV and drinking water standard



[Roux 17b]

Figure 18. Columbia Falls Anaconda Company groundwater samples that exceeded the nitrate drinking water standard and CVs for other chemicals



[Roux 17b]

Appendix B. Explanation of Evaluation Process

Screening Process

In evaluating data, we use comparison values (CVs) to determine which chemicals to examine further. ATSDR sets CVs assuming daily exposure to the chemical in a standard amount of air, water, and soil that someone might inhale or ingest each day without known or anticipated adverse human health effects. ATSDR develops different CVs for cancer and noncancer health effects. For chemicals for which both cancer and noncancer CVs exist, Montana DPHHS staff uses the lower CV level to be protective.
Health assessors list the CVs we used below:

Cancer Risk Evaluation Guides (CREGs) — are estimated contaminant concentrations that would be expected to cause no more than one additional excess cancer in 1 million persons exposed over a lifetime. CREGs are calculated from EPA cancer slope factors.

Environmental Media Evaluation Guides (EMEGs) — are estimated contaminant concentrations in a media where noncancer health effects are unlikely. EMEGs are derived from the ATSDR minimal risk level (MRL).

Reference Media Evaluation Guides (RMEGs) are estimated contaminant concentrations in a media where noncancer health effects are unlikely. RMEGs are derived from EPA's reference dose (RfD), an estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Regional Screening Levels (RSLs) are chemical-specific concentrations developed by EPA for individual contaminants in air, drinking water and soil that may warrant further investigation or site cleanup. RSLs are not cleanup standards.

Maximum Contaminant Levels (MCLs) are enforceable standards set by EPA for the highest level of a contaminant allowed in drinking water. MCLs are set as close to MCL goals (the level of a contaminant in drinking water below which there is no known or expected risk to health) as feasible using the best available treatment technology and taking cost into consideration.

If a chemical is present at a level higher than the corresponding comparison value, it means further evaluation is needed.

Estimation of Exposure Dose

For this report, we estimate the *exposure dose*, or the amount of contaminant that could get into a person's body for the ingestion pathway. We also estimate exposures for the dermal pathway, if dermal absorption information is available for the chemical. Health assessors express dose in milligrams of contaminant per kilogram of body weight of the person exposed, per day (mg/kg/day). These units allow us to compare site-related doses with toxicological studies.

To estimate doses, we use standard assumption factors about weight and other body characteristics of children and adults exposed, how they might be exposed, and how often they might be exposed [ATSDR 2005, EPA 2011]. Health assessors also assume the body absorbs 100% of the ingested chemical.

For large areas with many sample results, we estimate exposure point concentrations (EPCs) by assuming all data points within an area contribute equally to a person's or group's exposure. We use ProUCL [EPA 2018j], a statistical software package, to find the EPC. This software calculates a value that equals or exceeds the true arithmetic mean 95% of the time when calculated repeatedly for randomly drawn subsets of the data. Statisticians call this the 95% upper confidence limit (UCL) of the arithmetic mean. We use the EPC for the concentration (C) in the dose equation.

Ingestion of Chemicals in Drinking Water

ATSDR's PHAST tool estimates exposure doses for ingestion of contaminants in drinking water using the body weights (by age) and water ingestion rates in Table B-1 below. It calculates a dose using the equation:

$$\text{Dose} = (C \times IR \times EF \times CF)/BW\text{, where;}$$

C = Concentration in water
IR = Ingestion Rate from Table B-1
EF = Exposure Factor
CF = Conversion Factor
BW = Body Weight from Table B-1

For example, PHAST calculated average (CTE) and reasonable maximum exposure (RME) doses for each age/weight for homes with a low level of cyanide measured in well water (10 µg/L = 0.010 mg/L). In the following long-hand example, a child younger than 1-year-old (average weight 7.8 kg), drinking 0.504 liters of water a day (CTE) will receive a dose of:

$$Dose = (0.010\ mg/L \times 0.504\ L/day)/\ 7.8\ kg = 0.00065\ mg/kg/day$$

A child younger than 1-year-old (average weight 7.8 kg), drinking 1.113 liters of water a day (RME) will receive a dose of:

$$Dose = (0.010\ mg/L \times 1.113\ L/day)/\ 7.8\ kg = 0.0014\ mg/kg/day$$

The PHAST method uses this formula to calculate the doses in in Tables C-9 [ATSDR 2014].

Table B-1. Drinking water exposure pathway, Columbia Falls Aluminum Company site. Estimates for body weight and drinking water ingestion

Group	CTE (L/day)	RME (L/day)	Body Weight (kg)
Child Birth to < 1 years old	0.504	1.113	7.8
Child 1 to < 2 years old	0.308	0.893	11.4
Child 2 to < 6 years old	0.376	0.977	17.4
Child 6 to < 11years old	0.511	1.404	31.8
Child 11 to < 16 years old	0.637	1.976	56.8
Child 16 to < 21 years old	0.77	2.444	71.6
Adults (≥21 years old)	1.227	3.092	80

kg = kilogram; lb. = pound; L/day = liters per day.
Weight for children and adults obtained from Table 8-1 of [EPA 2011], recommended values for body weight (males and females combined). (Weighted averages used to obtain body weight for specific age ranges listed in this table.) Ingestion rates obtained from Tables 3-1 and 3-3 of [EPA 2011], consumers-only ingestion of drinking water, RME = 95th percentile, CTE = mean.

Ingestion of Chemicals in Surface Soil

ATSDR's PHAST method estimates exposure doses for incidental or accidental ingestion of contaminated soil using the weights and soil ingestion rates in Table B-2 below.

It calculates the dose using the equation:

Dose = (C × IR × EF ×CF)/BW, where;

C = Concentration in soil
IR = Ingestion Rate from Table B-1
EF = Exposure Factor (5/7 days per week × 26/52 weeks per year) = 0.4
CF = Conversion Factor
BW = Body Weight from Table B-1

For example, a worker older than 21-years-old (average weight 80 kg), incidentally ingesting 330 mg of soil per day (about 3 postage stamps weight) containing an average concentration of PAHs (60 mg/kg), 5 days a week, 26 weeks a year for 35 years will receive a dose calculated as follows:

Dose = (60 mg/kg×330 mg/day× 0.4 × 0.000001 kg/mg)/ 80 kg =0.000098 mg/kg/day

The PHAST method uses this formula to calculate the doses in in Tables C-19a [ATSDR 2014].

Table B-2. Soil ingestion exposure pathway, Columbia Falls Aluminum Company site. Estimates for body weight and soil ingestion

Group	Body Weight in Kilograms (Weight in Pounds)	Soil Ingestion mg/day CTE	Soil Ingestion mg/day RME	Frequency of Exposure in Days per Year‡	Duration of Exposure in Years
Children from 11 Years Old Up To Age 16	56.8 kg (lb)	100 mg/day	200 mg/day	72	5
Children from 16 Years Old Up To Age 21	71.6 kg (158 lb)	100 mg/day	200 mg/day	72	5
Adults Greater Than 21 Years Old	80 kg (176 lb)	50 mg/day	100 mg/day	72	10
Workers with high soil exposure	80 kg (176 lb)	330 mg/day		72	10

kg = kilogram; mg = milligrams lb. = pound; L/day = liters per day.
Incidental ingestion obtained from Table 5-1 of [EPA 2011], recommended values for daily soil + dust ingestion. Value for workers obtained from Exhibit 1-2 of [EPA 2002], for workers with high soil exposure.

Evaluating Noncancer Health Effects

Health assessors then compare the calculated exposure doses to an appropriate health guideline for that chemical. Health guideline values are considered safe doses; that is, health effects are unlikely below this level. The health guideline value is based on valid toxicological studies for a chemical, with appropriate safety factors built in to account for human variation, animal-to-human differences, and/or the use of the lowest study doses that resulted in harmful health effects (rather than the highest dose that did not result in harmful health effects). For noncancer health effects, the following health guideline values are used.

Minimal Risk Level (MRLs) – Developed by ATSDR
An MRL is an estimate of daily human exposure — by a specified route and length of time — to a dose of chemical that is likely to be without a measurable risk for adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects. A list of MRLs can be found at http://www.atsdr.cdc.gov/mrls/index.html.

Reference Dose (RfD) – Developed by EPA
The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs can be found at http://www2.epa.gov/iris.

If the estimated exposure dose for a chemical is less than the health guideline value, then the exposure is unlikely to cause a noncancer health effect in that specific situation. If the exposure dose for a chemical is greater than the health guideline, then we compare the exposure dose to known toxicological values for that chemical and discuss it in more detail in the public health assessment. These toxicological values are doses derived from human and animal studies that are summarized in the ATSDR Toxicological Profiles, reports included in EPA's Integrated Risk Information System, and in current scientific literature. A direct comparison of site-specific exposure and doses to study-derived exposures and doses that cause adverse health effects is the basis for deciding whether health effects are likely or not.

Evaluating Cancer Health Effects

The PHAST method estimates risk for developing cancer resulting from exposure to the contaminants by multiplying the site-specific estimated cancer dose by an appropriate cancer slope factor or inhalation unit risk (EPA cancer slope values can be found at http://www.epa.gov/iris). The result estimates the increase in risk of developing cancer after the exposure to the contaminant through the defined exposure scenario. ATSDR describes this estimated increased risk qualitatively and in terms of background rates of cancer occurring in the U.S. population.

There are many uncertainties in estimating cancer risk and risk estimation methods typically employ many conservative assumptions. The actual increased risk of cancer may be lower than the calculated number, which gives an estimated risk of excess cancer. ATSDR uses a weight-of-evidence approach in deciding whether exposures to cancer-causing contaminants are of concern.

PHAST uses the following cancer risk calculation. It assumes exposures of 21 years at various childhood weights and 12 years at ages 21 to 33 at adult weight.

$$\text{Dose} = (C \times IR \times EF \times CF)/BW$$
$$EF = (F \times ED)/AT$$
$$\text{Cancer risk} = CSF \times \text{cancer dose}$$

Assumptions:
C = concentration (site specific)
IR = ingestion rate (see Table B-2 for child and young adult ingestion rates)
BW = body weight (see Table B-2 for child and young adult body weights)
EF = exposure factor
F = frequency =350 days per year
ED = exposure duration = 33 years
CF = conversion factor (10^{-6} kg/mg)
AT = averaging time = 25,500 days (78 years)
CSF = cancer slope factor (chemical specific)

Public Health Evaluation of Potential for Vapor Intrusion from Contaminated Surficial Aquifer Groundwater [ATSDR 2016b]

Health assessors used ATSDR's air CVs, EPA's recommended screening attenuation factors [EPA 2015] and the following equation to derive a screening level for 1,2-dichloroethane in surficial aquifer groundwater to evaluate its vapor intrusion potential.

$CV_{gw} = CV_{air} / (H' * \alpha_{gw})$,

Where CV_{gw} = screening level in groundwater,

CV_{air} = ATSDR's air CV for 1,2-dichloroethane, CREG, (0.38 $\mu g/m^3$),

H' = (0.023) dimensionless less Henry's Law constant for 1,2-dichloroethane [http://www.nj.gov/dep/srp/guidance/rs/chemproperties.pdf], and

α_{gw} = EPA's recommended screening groundwater attenuation factor 0.001 [EPA 2015]

Simplify:

$CV_{gw} = (0.38\ \mu g/m^3) / (0.023 * 0.001)$

$CV_{gw} = 0.38\ \mu g/m^3 / 0.000023$

$CV_{gw} = 16{,}522\ \mu g/m^3$

As you want groundwater concentrations in µ/L, multiply by 0.001 m^3/L, so:

$CV_{gw} = 16{,}522\ \mu g/m^3 * 0.001\ m^3/L$ = *So the screening value will be*

$CV_{gw} = 16.5\ \mu g/L$ 1,2-dichloroethane *for surficial groundwater.*

The amount of 1,2-dichloroethane measured was 0.28 J µg/L (estimated value). Since this amount is so much lower than our calculated screening value, 16.5 µg/L, **vapor intrusion is not likely to be an issue** (the screening value is 58 times higher than the estimated value).

Appendix C. Additional Tables

Table C-1. Completed and potential human exposure pathways for the Columbia Falls Aluminum Company site

Pathway Name	**Pathway Source**	**Pathway Environmental Media**	**Pathway Point of Exposure**	**Pathway Route of Exposure**	**Pathway Exposed Population**	Time
Surface soil	Remnant aluminum production chemicals on the Columbia Falls Aluminum Company site	Surface soil	Surface soil	Ingestion and dermal	Workers, trespassers, and nearby residents	Past, present, and future
Sediments	Same as above	Sediments	Surface soil	Ingestion and dermal	Workers, trespassers, and nearby residents	Past, present, and future
Fish	Same as above	COPCs in groundwater and site discharges bioaccumulating in fish in the seeps area near Flathead River	Surface water/fish	Eating fish caught in seep areas	Recreationists accessing seeps via the Flathead River	Past, present, and future
Air	Same as above	Air and windblown dust from contaminants in soil	Outdoor air	Inhalation	Workers, trespassers, and nearby residents	Past, present, and future
Private wells	Same as above	Groundwater	Off-site private wells	Ingestion	Offsite residents	Past (for 2013 tests only)
Air	Plant emissions	Air	Indoor or outdoor air	Inhalation	Workers, trespassers, and nearby residents	Past

All are or were completed exposure pathways. Most could also be potential exposure pathways except private wells, which are being tested, and plant emission which have ceased.

Table C-2. Eliminated human exposure pathways for the Columbia Falls Aluminum Company site

Pathway Name	Pathway Source	Pathway Environmental Media	Pathway Point of Exposure	Pathway Route of Exposure	Pathway Exposed Population	Time
Groundwater vapors	Same as above	Trenches or building foundations	On-site construction areas that involve digging in soil	Inhalation	None	Past, present, and future
Vapor Intrusion	Same as above	Indoor and outdoor air	On-site, new buildings over contaminated shallow groundwater, possibly also construction trench air	Inhalation	None	Future
Surface water	Same as above	Surface water	Surface water	Ingestion, dermal and inhalation	Workers, trespassers, and nearby residents	Past, present, and future
Private wells	Same as above	On-site Groundwater	Planned property deed restrictions will prohibit use of groundwater as a source of drinking water. *	Ingestion, dermal and inhalation	None	Currently and in the future

*Arsenic, cyanide, fluorides, and nitrate in groundwater exceed drinking water standards onsite.

Table C-3. Contaminants of potential concern in Columbia Falls Aluminum Company site upper hydrogeologic unit groundwater

Contaminants of Potential Concern	**Concentration Range** (µg/L)	**Screening Guideline** (µg/L) *	**Source of Screening Guideline**	**# Above Screening Guideline/ Total #**
antimony	< 0.62 U to 4.4	2.8 6	ATSDR chr. child RMEG MCL and DEQ-7 WQS....	1/63 0/63
arsenic	<0.62 U to 1,330	0.016 2.1 10	ATSDR CREG………… ATSDR chr. child EMEG MCL and DEQ-7 WQS....	28/63 16/63 5/63
free cyanide	<1.5 U to 2,200	4.4 200	ATSDR chr. child EMEG MCL and DEQ-7 WQS....	30/63 1/63
total cyanide	<2 U to 8,120	4.4 200	ATSDR chr. child EMEG MCL and DEQ-7 WQS....	40/63 25/63
fluoride	<15 U to 55,300	4000	MCL and DEQ-7 WQS....	12/63
manganese	< 2.5 U to 1,450	350	ATSDR chr. child RMEG	6/63
nitrate	<100 U to 62,800	28,000 10,000	ATSDR chr. child EMEG MCL and DEQ-7 WQS....	4/63 7/63
selenium	<0.73 U to 96.8**	50	MCL and DEQ-7 WQS....	1/63
vanadium	<1.9 U to 3,350	70	ATSDR int. child EMEG	3/63

* Screening guidelines are used to select chemicals for further scrutiny, not to judge health risk.
** Only identified in Weston (2014) test results.
ATSDR = Agency for Toxic Substances and Disease Registry
CREG = ATSDR cancer risk evaluation guide for one in one million excess cancer cases.
EMEG = Environmental Media Evaluation Guide, intermediate (int.) refers to a 2 to 52-week exposure, chronic (chr.) refers to a longer than 52-week exposure.
RMEG = Reference Dose Media Evaluation Guide, chronic refers to a longer than 52-week exposure.
MCL = Enforceable EPA Drinking Water Standard, Maximum Concentration Level,
DEQ-7 = Montana Department of Environmental Quality, Enforceable Numeric Drinking Water Standards, from Circular DEQ-7
µg/L = micrograms per liter
U = Undetected, this number was the detection limit for a specific sample run.
Data sources: [Weston 2014; Roux 2017a, 2017b]

Table C-4a. Dioxin* Toxicity Equivalence Factors

Compound	WHO 1998 TEF	WHO 2005 TEF*
chlorinated dibenzo-p-dioxins		
2,3,7,8-TCDD	1	1
1,2,3,7,8-PeCDD	1	1
1,2,3,4,7,8-HxCDD	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1
1,2,3,4,6,7,8-HpCDD 0.01 0.01	0.01	0.01
OCDD	0.0001	**0.0003****
chlorinated dibenzofurans		
2,3,7,8-TCDF	0.1	0.1
1,2,3,7,8-PeCDF	0.05	**0.03**
2,3,4,7,8-PeCDF	0.5	**0.3**
1,2,3,4,7,8-HxCDF	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01
OCDF	0.0001	**0.0003**
non-ortho substituted PCBs		
PCB 77	0.0001	0.0001
PCB 81	0.0001	**0.0003**
PCB 126	0.1	1 0.1
PCB 169	0.01 0.03	**0.03**
mono-ortho substituted PCBs		
105	0.0001	**0.00003**
114	0.0005	**0.00003**
118	0.0001	**0.00003**
123	0.0001	**0.00003**
156	0.0005	**0.00003**
157	0.0005	**0.00003**
167	0.00001	**0.00003**
189	0.0001	**0.00003**

*The term "Dioxins" here refers to 7 dioxin and 10 furan chemical compounds.
**Numbers in bold indicate a change in TEF value [Van den Berg et al. 2006]

Table C-4b. CalEPA Polycyclic Aromatic Hydrocarbon Potency Equivalency Factors (PEFs)

Air Toxics Hot Spots Program Guidance Manual February 2015

TABLE G-2. OEHHA PEF WEIGHTING SCHEME FOR PAHS AND THEIR RESULTING CANCER POTENCY VALUES.[1]

PAH or derivative	PEF	Unit Risk $(\mu g/m^3)^{-1}$	Inhalation Slope Factor $(mg/kg\text{-}day)^{-1}$	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$
benzo[a]pyrene (index compound)	**1.0**	**1.1×10^{-3}**	**3.9**	**$1.2 \times 10^{+1}$**
benz[a]anthracene	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
benzo[b]fluoranthene	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
benzo[*j*]fluoranthene	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
benzo[k]fluoranthene	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
dibenz[*a,j*]acridine	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
dibenz[*a,h*]acridine	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
7H-dibenzo[c,g]carbazole	1.0	1.1×10^{-3}	3.9	$1.2 \times 10^{+1}$
dibenzo[*a,e*]pyrene	1.0	1.1×10^{-3}	3.9	$1.2 \times 10^{+1}$
dibenzo[*a,h*]pyrene	10	1.1×10^{-2}	$3.9 \times 10^{+1}$	$1.2 \times 10^{+2}$
dibenzo[*a,i*]pyrene	10	1.1×10^{-2}	$3.9 \times 10^{+1}$	$1.2 \times 10^{+2}$
dibenzo[*a,l*]pyrene	10	1.1×10^{-2}	$3.9 \times 10^{+1}$	$1.2 \times 10^{+2}$
indeno[1,2,3-*cd*]pyrene	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
5-methylchrysene	1.0	1.1×10^{-3}	3.9	$1.2 \times 10^{+1}$
1-nitropyrene	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
4-nitropyrene	0.1	1.1×10^{-4}	3.9×10^{-1}	1.2
1,6-dinitropyrene	10	1.1×10^{-2}	$3.9 \times 10^{+1}$	$1.2 \times 10^{+2}$
1,8-dinitropyrene	1.0	1.1×10^{-3}	3.9	$1.2 \times 10^{+1}$
6-nitrochrysene	10	1.1×10^{-2}	$3.9 \times 10^{+1}$	$1.2 \times 10^{+2}$
2-nitrofluorene	0.01	1.1×10^{-5}	3.9×10^{-2}	1.2×10^{-1}
chrysene	0.01	1.1×10^{-5}	3.9×10^{-2}	1.2×10^{-1}

[1]. Source: OEHHA (1993)

Office of Environmental Health Hazard Assessment, 2015. Air Toxics Hot Spots Program Appendices G-J, Guidance Manual for Preparation of Health Risk Assessments [CalEPA 2003]

Table C-5a. Contaminants of potential concern in private drinking water wells near the Columbia Falls Aluminum Company site.

Contaminants of Potential Concern	**Concentration Range** (μg/L)	**Screening Guideline** (μg/L) *	**Source of Screening Guideline**	**# Above Screening Guideline/ Total #**
total cyanide	<5 U to 111**	4.4 200	ATSDR chr. child EMEG MCL and DEQ-7 WQS....	3/22 0/22
fluoride	<15 U to 280	4000	MCL and DEQ-7 WQS....	0/22

* Screening guidelines are used to select chemicals for further scrutiny, not to judge health risk.
** Only identified in Weston [2014] test results.Weston tested five residential wells in 2013: one had cyanide at 111 μg/L (improperly sampled through a garden hose), a house on Cedar Creek Reservoir had 18.5 μg/L cyanide (upgradient from the site), another had cyanide at 10 μg/L, and two were cyanide non-detects: none exceeded the MCL. Roux sampled 17 wells from 2 to 14 times.
ATSDR = Agency for Toxic Substances and Disease Registry
EMEG = Environmental Media Evaluation Guide, intermediate refers to a 2 to 52-week exposure, chronic (chr.) refers to a longer than 52-week exposure.
MCL = Enforceable EPA Drinking Water Standard, Maximum Concentration Level,
DEQ-7 = Montana Department of Environmental Quality, Enforceable Numeric Drinking Water Standards, from Circular DEQ-7
μg/L = micrograms per liter
U = Undetected, this number was the detection limit for a specific sample run.

Data sources: [Weston 2014; Roux 2017a, 2017b].

Table C-6. Contaminants of potential concern in Columbia Falls Aluminum Company site surface water

Contaminants of Potential Concern	Concentration Range (µg/L)	Screening Guideline (µg/L) *	Source of Screening Guideline	# Above Screening Guideline/ Total #
arsenic	<0.62 U to 3.7 BCF = 44	0.016 2.1 10	ATSDR CREG………… ATSDR chr. child EMEG MCL and DEQ-7 WQS....	10/21 3/21 0/21
free cyanide	<1.5 U to 45.6	4.4 200	ATSDR chr. child EMEG MCL………………..........	3/21 0/21
total cyanide	<2 U to 209 BCF = 30	4.4 4 200	ATSDR chr. child EMEG DEQ-7 SW AQS……… MCL and DEQ-7 WQS....	11/21 11/21 2/21
fluoride	<15 U to 22,400 BCF = not given	4000	MCL and DEQ-7 WQS....	1/21

* Screening guidelines are used to select chemicals for further scrutiny, not to judge health risk.
ATSDR = Agency for Toxic Substances and Disease Registry
CREG = ATSDR cancer risk evaluation guide for one in one million excess cancer cases.
EMEG = Environmental Media Evaluation Guide, intermediate refers to a 2 to 52-week exposure, chronic (chr.) refers to a longer than 52-week exposure.
RMEG = Reference Dose Media Evaluation Guide, chronic refers to a longer than 52-week exposure.
MCL = Enforceable EPA Drinking Water Standard, Maximum Concentration Level,
DEQ-7 DWS = Montana Department of Environmental Quality, Enforceable Numeric Drinking Water Standards, from Circular DEQ-7
DEQ-7 AQS = Montana Department of Environmental Quality, Aquatic Life Standards, from Circular DEQ-7, fluoride doesn't have on and arsenic's is higher than the WQS, it's 150 µg/L
µg/L = micrograms per liter
U = Undetected, this number was the detection limit for a specific sample run.
Data sources: [Weston 2014; Roux 2017a, 2017b]
Data notes: The two cyanide exceedances are in the west seep by the river. One sample closer to the Flathead River was 36.2 µg/L.

Table C-7. Contaminants of potential concern in Columbia Falls Aluminum Company site surface soil (0 to 6 inches deep)

Contaminants of Potential Concern	Concentration Range (mg/kg)	Screening Guideline* (mg/kg)	Source of Screening Guideline	# Above Screening Guideline/ Total #
aluminum	2560 to 106,000	57,000	ATSDR chr. child EMEG	2/202
arsenic	< 0.84 U to 31.3	17 22.5	ATSDR chr. child EMEG DEQ MT soil background	2/202 2/202
copper	5.7 to 7,260	570	ATSDR acute/int. EMEG	2/202
cyanide, total	<0.36 U to 137	36	ATSDR chr. child RMEG	1/202
dioxin (TEQ) **	0.47×10^{-6} to 6.07×10^{-6}**	0.0000029 0.0000037 0.000057	ATSDR CREG DEQ MT Background ATSDR chr. child RMEG	2/13 1/13 1/13
fluoride	0.36 to 976	310	Residential EPA RSL	17/200
nickel	<0.033 to 1,250	1,100	ATSDR chr. child RMEG	1/202
polycyclic aromatic hydrocarbons (TEQ)	0.021 U to 143.57	0.016	ATSDR CREG	165/202

TEQ = Toxicity Equivalence Quotient, it is the sum of the toxicity of the chemical family components. See Tables C-4a and 4b.
ATSDR = Agency for Toxic Substances and Disease Registry
CREG = ATSDR cancer risk evaluation guide for 10^{-6} excess cancer risk
EMEG = Environmental Media Evaluation Guide, acute refers to less than 2-week exposure, intermediate refers to a 2 to 52-week exposure, chronic (chr.) to a longer than 52-week exposure.
mg/kg = milligrams per liter
* Screening guidelines only used to select chemicals for further scrutiny, not to judge the health risk.
** $\times 10^{-6}$ = units are parts per trillion or nanograms per kilogram ng/kg
Data sources: [Weston 2014; Roux 2017a, 2017b]

Table C-8. Contaminants of Potential Concern in Columbia Falls Aluminum Company site sediment (0 to 6 inches deep)

Contaminants of Potential Concern	Concentration Range (mg/kg)	Screening Guideline (mg/kg)	Source of Screening Guideline	# Above Screening Guideline/ Total #
aluminum	2560 to 112,000	57,000	ATSDR chr. child EMEG	1/19
arsenic	< 0.84 U to 26.4	17 22.5	ATSDR chr. child EMEG DEQ MT soil background	1/19 0/19
polycyclic aromatic hydrocarbons (TEQ)	0.021 U to 143.39	0.016	ATSDR CREG	8/19

TEQ = Toxicity Equivalence Quotient, it is the sum of the toxicity of the chemical family components.
ATSDR = Agency for Toxic Substances and Disease Registry
CREG = ATSDR cancer risk evaluation guide for 10^{-6} excess cancer risk
EMEG = Environmental Media Evaluation Guide, acute refers to less than 2-week exposure, intermediate refers to a 2 to 52-week exposure, chronic (chr.) to a longer than 52-week exposure.
mg/kg = milligrams per kilogram
* Screening guidelines only used to select chemicals for further scrutiny, not to judge the health risk.
Data sources: [Weston 2014; Roux 2017a, 2017b]

Abbreviations used on the dose calculation tables (C-9 through C-19) that follow

α = Hazard Quotient is above 1. Health assessor should investigate this level further.
ATSDR MRL = Minimal Risk Level. An estimate of the daily human exposure to a hazardous substance that is not likely to have an appreciable risk of adverse non-cancer health effects over a specified duration of exposure.
Chronic = Exposures lasting longer than a year, as opposed to intermediate exposures lasting 2 to 52 weeks, and acute exposures lasting 2 weeks or less.
Chronic dose = Dose for exposures lasting a year or longer.
CLT = Central Limit Theorem, a statistical theory that states the given a sufficiently large sample size from a population with a finite level of variance, the mean of all samples for the sample populations with be approximately equal to the average of the population.
CTE = Central Tendency Exposure; for water ingestion, 1 liter a day; for soil ingestion 100 milligrams per day
ED = Exposure duration, in years.
EPA RfD = Reference Dose. Estimate of a daily oral lifetime exposure for people, unlikely to have appreciable deleterious health effects.
EPC = Exposure Point Concentration = We used chemicals of potential concern exceeding their comparison values in EPA's statistical software, ProUCL 5.1, to calculate the 95th Percentile of the Arithmetic Mean.
Hazard Quotient = Our calculated dose divided by the MRL or RfD for that chemical.
NC = Not calculated.
Minimal Risk Level = ATSDR term, an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified exposure duration.
RME = Reasonable Maximum Exposure; for water ingestion, 2 liters a day; for soil ingestion 200 milligrams per day
mg/kg = milligrams per kilograms, or parts per million
Reference Dose = EPA term, an oral reference dose (abbreviated RfD) is an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
µg/L = micrograms per liter, or parts per billion
δ = A dermal dose could not be calculated because there is no dermal absorption factor for this contaminant. Therefore, results are for the ingestion pathway only.
Ω Cancer risks are not calculated for pregnant women and lactating women. Their cancer risks are like an adult woman exposed for 33 years. If you would like to calculate cancer risks for pregnant women and lactating women, enter site-specific scenarios.

Table C-9. Estimated doses for residents exposed to 10 and 18.5 µg/L cyanide-contaminated groundwater in private wells near the Columbia Falls Aluminum Company site. Default Residential Scenario

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk [§]			
	CTE	RME	CTE	RME	CTE	ED (yrs)	RME	ED (yrs)
CYANIDE (EPC: 0.01 mg/L; Chronic RfD: 0.00063 mg/kg/day; CSF: NA[3])								
Birth to < 1 year	0.00065	0.0014	1.0 [α]	2.3 [α]	NC	1	NC	1
1 to < 2 years	0.00027	0.00078	0.43	1.2 [α]		1		1
2 to < 6 years	0.00022	0.00056	0.34	0.89		4		4
6 to < 11 years	0.00016	0.00044	0.26	0.70		5		5
11 to < 16 years	0.00011	0.00035	0.18	0.55		1		5
16 to < 21 years	0.00011	0.00034	0.17	0.54		0		5
Total exposure duration for child cancer risk						12		21
Adult	0.00015	0.00039	0.24	0.61	NC	12	NC	33

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk [§]			
	CTE	RME	CTE	RME	CTE	ED (yrs)	RME	ED (yrs)
CYANIDE (EPC: 0.0185 mg/L; Chronic RfD: 0.00063 mg/kg/day; CSF: NA[3])								
Birth to < 1 year	0.0012	0.0026	1.9 [α]	4.2 [α]	NC	1	NC	1
1 to < 2 years	0.00050	0.0014	0.79	2.3 [α]		1		1
2 to < 6 years	0.00040	0.0010	0.63	1.6 [α]		4		4
6 to < 11 years	0.00030	0.00082	0.47	1.3 [α]		5		5
11 to < 16 years	0.00021	0.00064	0.33	1.0 [α]		1		5
16 to < 21 years	0.00020	0.00063	0.32	1.0 [α]		0		5
Total exposure duration for child cancer risk						12		21
Adult	0.00028	0.00072	0.45	1.1 [α]	NC	12	NC	33

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Table C-10. Estimated doses for ballplaying trespassers exposed to surface soils on fields on the western site of the Columbia Falls Aluminum Company site, EPC of 0.567 mg/kg TEQ PAHS. Site specific scenario.

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE	RME	CTE	RME	CTE	RME	ED (yrs)
BENZO(A)PYRENE (EPC: 0.567 mg/kg; Chronic RfD: 0.0003 mg/kg/day; CSF: 1 $(mg/kg/day)^{-1}$; ADAF mutagen)							
11 to < 16 years	4.6E-07	6.5E-07	0.0015	0.0022	1.1E-7	1.6E-7	5
16 to < 21 years	3.9E-07	5.4E-07	0.0013	0.0018			5
Total exposure duration for child cancer risk							10

Table C-11. Estimated doses for motorcycle or ATV riding trespassers exposed to surface soils on roads near the Columbia Falls Aluminum Company plant, EPC of 60.74 mg/kg TEQ PAHS. Site specific scenario.

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient			Cancer Risk		
	CTE	RME	CTE	RME		CTE	RME	ED (yrs)
	BENZO(A)PYRENE (EPC: 60.74 mg/kg; Chronic RfD: 0.0003 mg/kg/day; CSF: 1 $(mg/kg/day)^{-1}$; ADAF mutagen)							
6 to < 11 years	7.1E-05	0.00011	0.24	0.36		2.3E-5 ß	3.4E-5 ß	5
11 to < 16 years	4.8E-05	6.8E-05	0.16	0.23				5
	Total exposure duration for child cancer risk							10

Table C-12. Estimated doses for motorcycle or ATV riding trespassers exposed to surface soils on roads near the Columbia Falls Aluminum Company plant, EPC of 656.1 mg/kg fluoride. Site specific scenario.

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE	RME	CTE	RME	CTE	RME	ED (yrs)
FLUORIDE (EPC: 656.1 mg/kg; Chronic MRL/RfD: NA; CSF: NA[3]; (Ingestion Results Only [δ])							
11 to < 16 years	0.00022	0.00044	NC	NC	NC	NC	5
16 to < 21 years	0.00017	0.00035	NC	NC			5
Total exposure duration for child cancer risk							10

Table C-13. Estimated doses for motorcycle or ATV riding trespassers exposed to surface soils on roads near the Columbia Falls Aluminum Company plant, EPC of 27 mg/kg arsenic. Site specific scenario.

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE	RME	CTE	RME	CTE	RME	ED (yrs)
ARSENIC (EPC: 27 mg/kg; Chronic MRL: 0.0003 mg/kg/day; CSF: 1.5 $(mg/kg/day)^{-1}$)							
11 to < 16 years	6.3E-06	1.0E-05	0.021	0.034	1.1E-6 [β]	1.8E-6 [β]	5
16 to < 21 years	5.2E-06	8.4E-06	0.017	0.028			5
Total exposure duration for child cancer risk							10

Table C-14. Estimated doses for motorcycle or ATV riding trespassers exposed to surface soils on roads near the Columbia Falls Aluminum Company plant, EPC of 102,692 mg/kg aluminum. Site specific scenario.

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE	RME	CTE	RME	CTE	RME	ED (yrs)
ALUMINUM (EPC: 102,692 mg/kg; Chronic MRL: 1 mg/kg/day; CSF: NA[3])							
11 to < 16 years	0.029	0.054	0.029	0.054	NC	NC	5
16 to < 21 years	0.023	0.043	0.023	0.043			5
Total exposure duration for child cancer risk							10

Table C-15. Estimated doses for motorcycle or ATV riding trespassers exposed to surface soils on roads near the Columbia Falls Aluminum Company plant, EPC of 6,940 mg/kg copper. Site specific scenario.

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE	RME	CTE	RME	CTE	RME	ED (yrs)
COPPER (EPC: 6,940 mg/kg; Chronic MRL/RfD: NA; CSF: NA[3])							
11 to < 16 years	0.0019	0.0037	NC	NC	NC	NC	5
16 to < 21 years	0.0015	0.0029	NC	NC			5
Total exposure duration for child cancer risk							10

Table C-16. Estimated doses for motorcycle or ATV riding trespassers exposed to surface soils on roads near the Columbia Falls Aluminum Company plant, EPC of 0.00000631 mg/kg TEQ dioxins. Site specific scenario.

Exposure Group	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE	RME	CTE	RME	CTE	RME	ED (yrs)
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (EPC: 6.31E-06 mg/kg; Chronic RfD: 7E-10 mg/kg/day; CSF: 130000 $(mg/kg/day)^{-1}$)							
11 to < 16 years	2.1E-12	3.7E-12	0.0030	0.0053	3.2E-8	5.5E-8	5
16 to < 21 years	1.7E-12	3.0E-12	0.0024	0.0042			5
Total exposure duration for child cancer risk							10

Table C-17. Estimated doses for recreationalists accessing the site via surface water bodies and possibly exposed to sediments on the periphery of the Columbia Falls Aluminum Company site, average (CLT) of 0.84 mg/kg PAHS. Site specific scenario.

<table>
<tr><th rowspan="2">Exposure Group</th><th colspan="2">Chronic Dose (mg/kg/day)</th><th colspan="2">Chronic Hazard Quotient</th><th colspan="3">Cancer Risk</th></tr>
<tr><th>CTE</th><th>RME</th><th>CTE</th><th>RME</th><th>CTE</th><th>RME</th><th>ED (yrs)</th></tr>
<tr><td colspan="8">BENZO(A)PYRENE (EPC: 0.84 mg/kg; Chronic RfD: 0.0003 mg/kg/day; CSF: 1 (mg/kg/day)$^{-1}$; ADAF mutagen)</td></tr>
<tr><td>6 to < 11 years</td><td>6.8E-07</td><td>1.1E-06</td><td>0.0023</td><td>0.0035</td><td rowspan="3">2.4E-7</td><td rowspan="3">3.7E-7</td><td>5</td></tr>
<tr><td>11 to < 16 years</td><td>4.5E-07</td><td>6.6E-07</td><td>0.0015</td><td>0.0022</td><td>5</td></tr>
<tr><td>16 to < 21 years</td><td>3.8E-07</td><td>5.5E-07</td><td>0.0013</td><td>0.0018</td><td>5</td></tr>
<tr><td colspan="7">Total exposure duration for child cancer risk</td><td>15</td></tr>
<tr><td>Adult</td><td>1.6E-07</td><td>2.3E-07</td><td>0.00053</td><td>0.00077</td><td>7.1E-8</td><td>1.0E-7</td><td>35</td></tr>
</table>

On-site workers' surface soil exposure pathways dose tables —

C-18. Estimated doses for current or future workers exposed to surface soils near the Columbia Falls Aluminum Company plant, EPCs for chemical in table

Exposure Group	Site-Specific Scenario				Default Occupational Scenario			
	Chronic Dose (mg/kg/day)	Chronic Hazard Quotient	Cancer Risk	ED (yrs)	Chronic Dose (mg/kg/day)	Chronic Hazard Quotient	Cancer Risk	
							CTE (6.6 yrs)	RME (25 yrs)
BENZO(A)PYRENE (EPC: 60.74 mg/kg; Chronic RfD: 0.0003 mg/kg/day; CSF: 1 $(mg/kg/day)^{-1}$; ADAF mutagen)								
Workers - indoor					2.6E-05	0.087	2.2E-6 [β]	8.3E-6 [β]
Workers - outdoor (low intensity soil contact)					5.2E-05	0.17	4.4E-6 [β]	1.7E-5 [β]
Workers - outdoor (high intensity soil contact)	8.9E-05	0.30	4.0E-5 [β]	35	0.00017	0.57	1.5E-5 [β]	5.5E-5 [β]
ALUMINUM (EPC: 102,092 mg/kg; Chronic MRL: 1 mg/kg/day; CSF: NA[3])								
Workers - indoor					0.044	0.044	NC	NC
Workers - outdoor (low intensity soil contact)					0.087	0.087	NC	NC
Workers - outdoor (high intensity soil contact)	0.15	0.15	NC	35	0.29	0.29	NC	NC
FLUORIDE (EPC: 656.1 mg/kg; Chronic MRL/RfD: NA; CSF: NA[3])								
Workers - indoor					0.00028	NC	NC	NC
Workers - outdoor (low intensity soil contact)					0.00056	NC	NC	NC
Workers - outdoor (high intensity soil contact)	0.00096	NC	NC	35	0.0019	NC	NC	NC
ARSENIC (EPC: 27 mg/kg; Chronic MRL: 0.0003 mg/kg/day; CSF: 1.5 $(mg/kg/day)^{-1}$)								
Workers - indoor					6.9E-06	0.023	8.8E-7	3.3E-6 [β]
Workers - outdoor (low intensity soil contact)					1.4E-05	0.046	1.8E-6 [β]	6.7E-6 [β]
Workers - outdoor (high intensity soil contact)	2.4E-05	0.079	1.6E-5 [β]	35	4.6E-05	0.15	5.8E-6 [β]	2.2E-5 [β]
COPPER (EPC: 6,940 mg/kg; Chronic MRL/RfD: NA; CSF: NA[3])								
Workers - indoor					0.0030	NC	NC	NC
Workers - outdoor (low intensity soil contact)					0.0059	NC	NC	NC
Workers - outdoor (high intensity soil contact)	0.010	NC	NC	35	0.020	NC	NC	NC

C-19. Estimated doses for current or future workers exposed to surface soils near the Columbia Falls Aluminum Company plant, EPC of 0.00000631 mg/kg dioxin TEQ

Exposure Group	Site-Specific Scenario				Default Occupational Scenario			
	Chronic Dose (mg/kg/day)	Chronic Hazard Quotient	Cancer Risk	ED (yrs)	Chronic Dose (mg/kg/day)	Chronic Hazard Quotient	Cancer Risk	
							CTE (6.6 yrs)	RME (25 yrs)
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (EPC: 6.31E-06 mg/kg; Chronic RfD: 7E-10 mg/kg/day; CSF: 130000 (mg/kg/day)$^{-1}$)								
Workers - indoor					3.1E-12	0.0044	3.4E-8	1.3E-7
Workers - outdoor (low intensity soil contact)					5.8E-12	0.0083	6.4E-8	2.4E-7
Workers - outdoor (high intensity soil contact)	9.5E-12	0.014	5.5E-7	35	1.8E-11	0.026	2.0E-7	7.6E-7

Appendix D. Chemical-Specific Toxicity Information

To evaluate possible public health implications, estimates of opportunities for exposure to compounds (calculated exposure doses) must be combined with what is known about the toxicity of the chemicals.

Chemicals of concern only identified in onsite groundwater
We do not include chemical-specific toxicity information for antimony, manganese, nitrate, selenium, or vanadium. These chemicals are not known to cause cancer and are present above their comparison values only in onsite groundwater. We do not have any information showing people may have been, or may be, exposed. Currently, power is not available for the pumps on former process wells that tap site groundwater and that did not show contamination in the past. Other onsite wells are for monitoring and do not have permanent pumps. While the owner may prevent peoples' exposures to onsite contaminated groundwater with deed-restrictions that prohibit its use, remediation will likely address offsite movement of contaminated groundwater.

Aluminum [ATSDR 2008]
Aluminum is the most abundant metal in the earth's crust and is widely distributed in many kinds of rock. Aluminum-containing soil from the tropics (bauxite) is the primary source of ore used in aluminum reduction facilities. High levels of aluminum measured on the site likely came from plant emissions. Ingesting aluminum from soil or sediment on your hands or from hand to mouth activities such as eating or smoking are the most likely ways for a person to be exposed at the site. Only a small amount of aluminum can be absorbed through the skin from contact with aluminum-contaminated soils.

Workers who breathe large amounts of aluminum dusts can have lung problems, such as coughing or changes that show up in chest X-rays. The use of breathing masks and controls on the levels of dust in factories have largely eliminated this problem. Some workers who breathe aluminum-containing dusts or aluminum fumes have decreased performance in some tests that measure functions of the nervous system. Studies in animals also show that the nervous system is the sensitive target of aluminum toxicity.

In people, ingestion of aluminum is usually not harmful. Some people who have kidney disease store a lot of aluminum in their bodies. Kidney disease causes less aluminum to be removed from the body in the urine. Sometimes, these people developed bone or brain diseases that doctors think were caused by excess aluminum. Although aluminum-containing over the counter oral products are considered safe in healthy individuals at recommended doses, some adverse effects have been observed following long-term use in some individuals.

People might be exposed to aluminum in some cosmetics, antiperspirants, and pharmaceuticals such as antacids and buffered aspirin. Antacids have 300–600 mg aluminum hydroxide (approximately 104– 208 mg of aluminum) per tablet, capsule, or 5 milliliter (mL) liquid dose. Little of this form of aluminum is taken up into the bloodstream. Buffered aspirin may contain 10–20 mg of aluminum per tablet. Vaccines may contain small amounts of aluminum compounds, no greater than 0.85 mg/dose.

Some studies show that people exposed to high levels of aluminum may develop Alzheimer's disease, but other studies have not found this to be true. We do not know for certain that aluminum causes Alzheimer's disease.

We do not know if aluminum will cause birth defects in people. Birth defects have not been seen in animal studies.

Aluminum is not classed as a carcinogen.

Arsenic [ATSDR 2007b, 2016a]
Arsenic is a naturally occurring element that can be found in many kinds of rock, particularly copper- or lead-containing ores. Arsenic can be found in the environment in two different forms, organic arsenic and inorganic arsenic. The organic forms are usually less harmful than the inorganic forms. Ingesting arsenic from soil or sediment on your hands or from hand to mouth activities such as eating, or smoking are the most likely way for a person to be exposed at this site. Arsenic is present in surface water samples at low levels, but not above the drinking water standard. Only a small amount of arsenic can be absorbed through the skin from contact with arsenic-contaminated soils or water. Some Montana soils contain naturally high levels of arsenic, and DEQ has set a statewide arsenic background at 22.5 mg/kg.

Nerve damage may be the first or only sign of long-term arsenic poisoning. Called peripheral neuropathy, this type of nerve damage means the loss of feeling and movement ability of individual nerves in the hands and feet [Guha 2003]. Another adverse health effect associated with long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include patches of lightened or darkened skin and the appearance of small "corns" or "warts" on the palms, soles, and torso, often associated with changes in the blood vessels of the skin. A study finding these dermatological effects was the basis for the Minimal Risk Level (MRL), which had a Lowest Observable Adverse Effect Level (LOAEL) of 0.014 mg/kg/day [Tseng et al. 1968, in ATSDR 2007b].

Inorganic arsenic is a known human carcinogen. From low to high daily doses, studies have linked chronic arsenic exposures to cancers of the lung, bladder, squamous skin cells, basal skin cells, liver, interior blood vessel surface linings (hemangioendothelioma), urinary tract, intraepidermal skin cells (located or occurring within the skin, this type of cancer is also known as Bowen's disease), and kidney transitional cells.

Arsenic exposure has been associated with neural tube birth defects in animals. One case control study suggests that exposure to arsenic in drinking water reduces the effectiveness of folic acid supplementation in preventing neural tube defects [Muzumdar et al. 2015]. Researchers linked elevated exposure to arsenic *in utero* and in early childhood to increased mortality in young adults from lung cancer and bronchiectasis (abnormal widening of the lobes of the lungs or their branches, causing a risk of infection) [Smith et al. 2006].

Copper [ATSDR 2004]
Copper is a naturally occurring element that can be found in many kinds of rock. High concentrations were measured on the CFAC site in waste disposal areas and near the plant. Currently, workers might be exposed to copper in these areas by swallowing soil from hand-to-mouth activities.

Copper is essential for good health. However, exposure to higher doses can be harmful. Long term exposure to copper dust can irritate your nose, mouth, and eyes, and cause headaches, dizziness, nausea, and diarrhea. EPA does not classify copper as a human carcinogen because there are no adequate human or animal cancer studies.

Cyanide [ATSDR 2006]
Cyanide formed during aluminum reduction heating processes. Some was emitted into the air, and some attached to the potliners. Cyanide is mobile in soil. At high concentrations, cyanide becomes toxic to soil microorganisms. Because these microorganisms can no longer change cyanide to other chemical forms, cyanide can pass through soil into groundwater. On the site, cyanide exposures might occur via ingestion of soil from hand-to-mouth activities, primarily in the waste disposal areas, or through surface water contact.

The severity of the harmful effects following cyanide exposure depends in part on the form of cyanide. Some of the first indications of cyanide poisoning are rapid, deep breathing and shortness of breath, followed by convulsions (seizures) and loss of consciousness. These symptoms can occur rapidly, depending on the amount taken in. Exposure to high levels of cyanide for a short time harms the brain and heart and can even cause coma and death. The health effects of large amounts of cyanide are similar, whether you eat, drink, or breathe it.

From occupational studies (not from CFAC workers) we know workers who inhaled low levels of hydrogen cyanide over a period of years had breathing difficulties, chest pain, vomiting, blood changes, headaches, and enlargement of the thyroid gland [ATSDR 2006]. Cyanide uptake into the body through the skin is slower than these other means of exposure. Skin contact with hydrogen cyanide or cyanide salts can cause irritation and produce sores.

There are no reports that cyanide can cause cancer in people or animals. EPA has determined that cyanide is not classifiable as to its human carcinogenicity.

Effects reported in exposed children are like those seen in exposed adults. Children who ate large quantities of apricot pits, which naturally contain cyanide as part of complex sugars, had rapid breathing, low blood pressure, headaches, and coma, and some died.

Cyanide has not been reported to directly cause birth defects in people. Among people in the tropics who eat improperly prepared cassava root, children have been born with thyroid disease because of their mothers' exposure to cyanide and thiocyanate during pregnancy. Birth defects occurred in rats that ate cassava root diets, and harmful effects on the reproductive system occurred in rats and mice that drank water containing sodium cyanide.

Cyanide was detected below the drinking water standard in offsite wells in 2013. In trying to determine if the low cyanide levels in these well tests could have had health effects (if these levels had been verified) showed EPA uses a very large uncertainty factor for relating animal study data to human health, for cyanide exposures. As a result, the critical effect level reported for animals is 3,000 times lower than the minimal risk level for humans. This large uncertainty factor added to the difficulty in interpreting whether the water levels could have been harmful.
EPA's explanation for using an uncertainty factor (UF) of 3,000 [EPA 2018a]:

- × 10 – uncertainties in extrapolating from laboratory animals to humans as the available data do not provide quantitative information on the difference in susceptibility to cyanide between rats and humans, and a wide range of sensitivity effects of cyanide has been observed between different species of experimental animals.
- × 10 – variations in susceptibility among members of the human population (i.e., interindividual variability) as insufficient information is available to quantitatively estimate variability in human susceptibility to cyanide.
- × 10 – the extrapolation of subchronic-to-chronic exposure duration. The 91-day study by National Toxicology Program (NTP) (1993) falls well short of a lifetime duration in rats. In addition, there is a lack of data on male reproductive parameters following chronic administration of cyanide, and the mode of action of the reproductive effects observed in this study is unclear. Therefore, it is unknown whether effects would be more severe or would be observed at lower doses with a longer exposure duration, and
- × 3 – to account for deficiencies in the cyanide toxicity database, including the lack of a multigenerational reproductive toxicity study and a sensitive neurodevelopmental toxicity study.

Dioxins [ATSDR 1998, 2012]
TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) is one of 75 different congeners of chlorinated dibenzo-p-dioxins (CDDs). Congeners are chemically similar but have different carbons in their carbon-rings chlorinated; position of the chlorine atoms affects each individual congeners' toxicity. The dioxin toxicity equivalence (TEQ) sums the more toxic congers to give an estimate of the total toxicity of the dioxin mixture. Dioxins are not intentionally manufactured but can be formed in the process of chlorinating phenols. Dioxins on the site are likely to have come from heating PCBs in rectifier yard transformers or capacitors. Some of these materials were reportedly spilled in this area in the past. People touching contaminated soil in this area might ingest dioxins from hand-to-mouth activities.

ATSDR has developed an MRL for TCDD of 1×10-9 milligrams per kilogram per day (mg/kg/day), or 1 picogram per kilogram per day (pg/kg/day) (ATSDR 1998). This was based on an LOAEL for neurobehavioral developmental effects in the offspring of exposed female rhesus monkeys of **1.2×10^{-7} mg/kg/day** [ATSDR 1998, ATSDR 2012]. EPA RfD **(7×10^{-9} mg/kg/day)** studies found reproductive and endocrine effects [EPA 2017a]. Critical effects include decreased sperm count and motility in men exposed to dioxin as boys, and increased thyroid stimulating hormone in exposed infants from hypothyroidism [EPA 2017b]. Hypothyroidism slows the body's metabolism and if untreated even mild cases in infants can lead to severe physical and mental retardation [Mayo Clinic 2018].

Carcinogenicity from exposure to dioxins is known from animal studies and human epidemiological studies. In animals, daily ingestion of low dioxin doses significantly increased the incidence of thyroid follicular cell adenoma, cancer of the liver, and other sites. In humans, possible elevated cancer risks are linked to soft-tissue sarcomas: non-Hodgkin's lymphoma, malignant lymphoma, respiratory tract cancer, breast cancer and gastrointestinal organ cancers (kidney, bladder, prostate).

Fluoride [ATSDR 2003]
Fluoride was a component of the fluxing minerals used to melt aluminum from alumina ore. Fluxes removed impurities from molten aluminum and rendered the ash and ore residuals (slag) more liquid at the smelting temperature, easing the separation of metal and slag. Workers and nearby residents may have been exposed to fluoride emissions in the past, people touching contaminated soil could be exposed now via incidental ingestion from hand-to-mouth activities.

Small amounts of fluoride are added to toothpaste or drinking water to help prevent dental decay. However, exposure to higher levels of fluoride may harm your health. Skeletal fluorosis can be caused by eating, drinking, or breathing very large amounts of fluorides. This disease only occurs after long-term exposures and can cause denser bones, joint pain, and limited range of joint movement. In the most severe cases, the spine is completely rigid.

Skeletal fluorosis is extremely rare in the United States; it has occurred in some people consuming greater than 30 times the amount of fluoride typically found in fluoridated water. At fluoride levels 5 times greater than levels typically found in fluoridated water, fluoride can result in denser bones. However, these bones are often more brittle or fragile than normal bone and there is an increased risk of older men and women breaking a bone.

When you breathe in air containing hydrogen fluoride or fluoride dusts, it enters your bloodstream quickly through your lungs. People breathing hydrogen fluoride have complained of eye, nose, and skin irritation. Breathing in a large amount of hydrogen fluoride with air can also harm the lungs and heart. Kidney and testes damage have been observed in animals breathing hydrogen fluoride. Exposure to very high concentrations of fluorine can cause death due to lung damage.

When hydrofluoric acid touches skin, most of it can quickly pass through the skin into the blood. How much of it enters your bloodstream depends on how concentrated the hydrofluoric acid is and how long it stays on your skin. Almost all the fluoride that enters the body in these ways is quickly removed from the body in the urine, but some is stored in your bones and teeth.

Most studies have not found any association between fluoride and cancer in people. The International Agency for Research on Cancer (IARC) has determined that the carcinogenicity of fluoride to humans is not classifiable.

Several human studies found an increase in birth defects or lower Intelligence Quotient (IQ) scores in children living in areas with very high levels of fluoride in the drinking water. Those studies did not adequately access other factors that could have contributed to the effects. Another study did not find birth defects in children living in areas with low levels of fluoride. Birth defects have not been found in most studies of laboratory animals.

Fluoride is not known to cause cancer.

Nickel [ATSDR 2005b]
Nickel is a naturally occurring element that can be found in many kinds of rock. One percolation pond sample showed nickel above acceptable residential soil levels for children where people might be exposed through soil ingestion from hand-to-mouth activities.

The most commonly reported adverse health effect associated with nickel exposure is contact dermatitis. Contact dermatitis is the result of an allergic reaction to nickel that has been reported in the general population and workers exposed via dermal contact with airborne nickel, liquid nickel solution, or prolonged contact with metal items such as jewelry and prosthetic devices that contain nickel. After an individual becomes sensitized to nickel, dermal contact with a small amount of nickel or oral exposure to low doses of nickel can result in dermatitis. Approximately 10–20% of the general population is sensitized to nickel.

The carcinogenicity of nickel has been well documented in occupationally-exposed individuals. Significant increases in the risk of mortality from lung or nasal cancers were observed in several cohorts of nickel refinery workers. Studies of workers in other nickel industries, including nickel mining and smelting, nickel alloy production, stainless steel production, or stainless-steel welding, which typically involve exposure to lower concentrations of nickel, have not found significant increases in cancer risks.

PAHs [EPA 2018b, c]
Polycyclic Aromatic Hydrocarbons (PAHs) are products of incomplete combustion of organic materials. They are a family of chlorinated chemicals, like the dioxins, and have a similar summing of congeners to determine the toxicity of the mixture measured. Petroleum and coal coke were heated as pot liner and anode materials during plant

operations. Workers and nearby residents may have been exposed to PAH emissions in the past from the heating of the potliners and anodes. People touching contaminated soil and sediment could be exposed now via incidental ingestion from hand-to-mouth activities.

Most aquatic organisms metabolize benzo[a]pyrene, a representative PAH; eliminating it in days, and thus, it is not expected to bioconcentrate in these organisms; however, several aquatic organisms such as plankton, oysters, and some fish cannot metabolize benzo[a]pyrene. Thus, the data on benzo[a]pyrene bioconcentration in aquatic organisms may vary from low to very high [HSDB, 2012]. PAHs were measured in sediments but not surface water.

PAHs are also released into the atmosphere as components of smoke from forest fires, vehicle exhaust, cigarettes, and through the burning of fuel (such as wood, coal, and petroleum products). Oral exposure to benzo[a]pyrene can occur by eating certain food products, such as charred meats, where benzo[a]pyrene is formed during the cooking process, or by eating foods grown in areas contaminated with benzo[a]pyrene (from the air and soil). Dermal exposure may occur from contact with soils or materials that contain soot, tar, or crude petroleum products or by using certain pharmaceutical products containing coal tars, such as those used to treat the skin conditions, eczema and psoriasis. The magnitude of human exposure to benzo[a]pyrene and other PAHs depends on factors such as lifestyle (e.g., diet, tobacco smoking), occupation, and living conditions (e.g., urban versus rural setting, domestic heating, and cooking methods).

Animal studies demonstrate that exposure to benzo[a]pyrene is associated with developmental (including developmental neurotoxicity), reproductive, and immunological effects. In addition, epidemiology studies involving exposure to PAH mixtures have reported associations between internal biomarkers of exposure to benzo[a]pyrene (benzo[a]pyrene diol epoxide-DNA adducts) and adverse birth outcomes (including reduced birth weight, postnatal body weight, and head circumference), neurobehavioral effects, and decreased fertility.

Studies in multiple animal species demonstrate that benzo[a]pyrene is carcinogenic at multiple tumor sites. These include the alimentary tract (the esophagus, stomach, and small and large intestines), liver, kidney, respiratory tract, pharynx (the membrane-lined cavity behind the nose and mouth that connects them to the esophagus), and the skin; by all routes of exposure. In addition, there is strong evidence of carcinogenicity in occupations involving exposure to PAH mixtures containing benzo[a]pyrene, such as aluminum production, chimney sweeping, coal gasification, coal-tar distillation, coke production, iron and steel founding, and paving and roofing with coal tar pitch. An increasing number of occupational studies demonstrate a positive exposure-response relationship with cumulative benzo[a]pyrene exposure and lung cancer.

Mixtures

ATSDR did not study mixtures of the chemicals found on this site. Some of these chemicals do cause cancers of the same types or in the same systems. Studies show:

- PAHs, nickel, arsenic, and dioxin are linked with respiratory system cancers [EPA 2018c, ATSDR 2005, ATSDR 2016a, 2007a, 2007b; ATSDR 1998, 2012; EPA 2017a, b];
- PAHs, arsenic, and dioxin are linked with liver, kidney, and bladder cancer [EPA 2018c, ATSDR 2016a, 2007b; ATSDR 1998, 2012; EPA 2017a, b];
- PAHs and arsenic are linked with skin cancer [EPA 2017a, b; ATSDR 2016a, 2007b];
- PAHs and nickel are linked with nasal cancer [EPA 2017a, b; ATSDR 2005, 2007b];
- PAHs and dioxin are linked with pharynx cancer [EPA 2017a, b; ATSDR 1998, 2012].

Occupational Exposure Studies of Aluminum Reduction Plant Workers

Health effects from mixtures of aluminum production emissions are known from workers' studies. Workers' mid-20th century exposures in aluminum reduction plants were likely higher due to less frequent use of personal protective equipment and higher emissions rates from production machinery with less efficient emission controls.

An early occupational study of over 20,000 workers with longer than 5 years employment in three types of aluminum reduction plants (prebake, vertical-, and horizontal-Søderberg processes) found higher than expected deaths from pancreatic cancer, cancers of immune system components (lymphohematopoietic cancers), and genitourinary cancers [Rockette and Arena 1983]. They found: 1) potroom workers in all three processes had an increased risk of stomach cancer, and 2) potroom and carbon bakers in the anode prebaking process had an excess of lung cancers. Other adverse health effects noted in this and other studies included nonmalignant respiratory disease (asthma, emphysema, chronic obstructive pulmonary disease) and benign and unspecified neoplasms. Neoplasms are new and abnormal tissue growths, characteristic of cancer. Later studies of Søderberg-process aluminum reduction plant potroom workers [Sim and Benke 2003], also showed increased risk of lung and bladder cancer.

A more recent occupational study of aluminum reduction plant workers found increased risks of bladder and stomach cancer related to cumulative exposure to PAHs, and risks for lung cancer, non-Hodgkin lymphoma, and kidney cancer increasing with increasing exposure to PAHs — although the overall rates were like those of the general population [Spinelli et al. 2006]. Analysis of the joint effect of smoking and coal tar pitch volatiles exposure on cancer showed the observed dose-response relationships to be independent of smoking [Spinelli et al 2006].

In India, people may have higher background fluoride exposures from native foods and water than aluminum reduction plant workers in the US do. As a result, they may see symptoms from fluoride exposures more rapidly than workers in other countries. For the Indian smelter workers with existing fluoride exposures, inhalation or ingestion of additional fluoride at work caused — within a few weeks — gastrointestinal discomfort, excessive urination, excessive thirst, muscle weakness, and anemia [Susheela et al. 2013]. Excess fluoride levels lead to a drop in red blood cells, as fluoride interferes with thyroid hormone production leading to diminished stimuli for red blood cell synthesis. Fluoride destroys probiotics responsible for production of vitamin B12, an essential constituent for red blood cell production [Sahashi et al. 1953]. And fluoride is responsible for loss of microvilli in the gastrointestinal mucosa, leading to non-ulcer dyspepsia (acid reflux) and irritable bowel syndrome while contributing to anemia due to malabsorption of food nutrients [Susheela et al. 2013].

Worker studies found excess fluoride intake caused derangement of muscle structure resulting in muscle weakness [Kaul and Susheela 1976, Kant et al. 2001]. Allergic reactions presenting as painful skin rashes due to perivascular inflammation, was also reported among the aluminum smelter workers and supervisors working in a smelter unit [Spittle 1993]. Skeletal manifestations in workers due to long-term exposure to excess fluoride first causes pain and stiffness in major joints because excess fluoride tends to accumulate more in cancellous bone (the spongy bone present at the ends of long bones, near and including the joints) compared to cortical bone (bone in the harder portions of the long bones) [Boillat et al. 1980, Runge and Franke 1989, Susheela and Jain 1986]. As the cancellous bone predominates in joint regions, the higher fluoride accumulation leads to damage to the bone matrix with resultant rigidity and stiffness of joints causing joint pain. By the time joint pain occurs, the reversal of the fluoride damage is unlikely, so early diagnosis is important [Susheela et al. 2013].

Other potential occupational-exposure health effects for aluminum reduction include asbestosis, mesothelioma, and silicosis due to inhalation of particulates, and hearing loss from plant noise [Susheela et al. 2013]. Workers can wear protective gear (respirators and hearing protection) to prevent these and other health effects. Historical reports of CFAC workers' health concerns are listed in the on-line book *From Superstar to Superfund* in chapters 22 and 23 [Hanners 2018].

Appendix E: Community health concerns about birth defects, cancer, and specific diseases

Birth defects: Community members wondered if birth defects were more common in Columbia Falls than other areas of Montana. Montana does not have a Birth Defects Registry and although some birth defects information may be included on birth and death records, such information would be incomplete (personal communication with Todd Koch, DPHHS vital statics, February 21, 2018).

Testing found PAHs and fluoride most frequently in on-site surface soil and sediment. Currently, little offsite data except private well test results, are available; therefore, we are unable to evaluate the potential for offsite exposures, including those that could potentially have caused birth defects.

Animal studies have associated elevated PAH exposures with developmental neurotoxicity, reduced birth weight, reduced weight after birth, and smaller head circumference. Occupational studies and drinking water studies with high fluoride exposure levels have shown fluoride is also neurotoxic. While elevated exposures to arsenic and dioxin have also been linked with birth defects (Appendix D), both were identified infrequently above their screening levels in onsite surface soil. Cyanide is found in surface water on the site, mostly at low levels. Studies show babies whose mothers' food had elevated levels of cyanide could be born with thyroid disease that caused slowed growth and development.

Cancer: DPHHS considered that looking for rates of cancers identified in occupational studies of aluminum reduction plant workers (with higher rates of exposures and exposures to mixtures of chemicals) would be more accurate than predicting what cancers exposed people might develop based on the occurrence of residual chemicals that were individually evaluated for carcinogenicity. Worker studies found increases in stomach, pancreatic, immune system, reproductive and urinary cancers [Rockette and Arena 1983]; lung and bladder cancers [Sim and Benke 2003]; and asbestosis, mesothelioma, and silicosis [Susheela et al. 2013].

DPHHS compared cancer age-adjusted incidence and mortality rates for Flathead County with Montana state-wide rates for stomach, pancreas, lung and bronchus, urinary bladder, kidney and renal pelvis, Hodgkin's and non-Hodgkin's lymphomas, mesothelioma, and male and female genital cancers. Flathead County had a statistically higher cancer incidence rate for prostate cancer from 2011 to 2016. The increased prostate cancer incidence rate may be due to more screening or more aggressive diagnosis because the Flathead County and state death rates for prostate cancer were not statistically different for this period. The incidence and mortality rates for all other types of cancers among Flathead County residents were statistically equal to Montana during this period (emails from Heather Zimmerman, Montana Cancer Control Programs, epidemiologist, February 15, 2018; June 21, 2018).

Specific Diseases:
Community members asked about Lupus, Carcinoid Tumors, Hashimoto's Disease, Sjogren's Syndrome, and Scleroderma/Raynaud's Syndrome (dual diagnosis). Except for Carcinoid Tumors, these are autoimmune diseases, meaning diseases in which the body's immune system attacks its own tissues and organs. We cannot say if these diseases occur more frequently in the Columbia Falls community than they do in other Montana communities as autoimmune diseases are not reportable diseases.

While the causes of autoimmune diseases are generally not known, predisposed people may experience a trigger. Triggers for lupus can be sunlight, infections, or medications for blood pressure, seizures, and antibiotics. Hashimoto's Disease and Sjogren's Syndrome may be triggered by infections. Scleroderma triggers may be exposure to pesticides, epoxy resins, or solvents.

These autoimmune diseases have common risk factors: being female, older than 15, and having a family history of autoimmune disease. In addition to these risk factors, Hashimoto's Disease, an autoimmune disease of the thyroid, occurs more often in people with exposure to excessive levels of environmental radiation, or a family history of thyroid disease. Both lupus and scleroderma are more common in women of Hispanic-, African-, Native- and Asian-American descent [Mayo Clinic 2018].

For peer-reviewed, easy to understand, medical information about these individual illnesses we direct the reader to the secure Mayo Clinic website: https://www.mayoclinic.org/diseases-conditions/, where you can find information on disease symptoms, diagnoses, treatment, and complications.

DPHHS was unable to find scientific studies linking autoimmune diseases with exposures to the chemicals found by onsite testing.

Studies have found an association between Hashimoto's Disease (an autoimmune thyroid disease) and other autoimmune diseases. A review of scientific studies suggested other autoimmune disorders should be considered in patients with Hashimoto's Disease who develop new or nonspecific symptoms [Braunstein 2010].

Glossary

Absorption
The process of taking in. For a person or animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time, [compare with **chronic**].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with **intermediate duration exposure** and **chronic exposure]**.

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems.

Aquifer
A layer of underground porous rock, gravel, sand, or silt containing enough groundwater to supply springs or wells.

Association
In statistics, a relationship between two measured quantities that means changes in one quantity can predict changes in the other. The relationship is not necessarily causal; that is, changes in one quantity do not necessarily cause the changes observed in the other quantity.

Cancer
A group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 33 years and averaging this risk over a 78-year lifespan (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Chronic
Occurring over a long time (more than 1 year) [compare with **acute**].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with **acute exposure** and **intermediate duration exposure**].

Comparison Value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level

during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Demographic
Pertaining to statistical characteristics of human populations.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see **route of exposure**].

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease registry
A system of ongoing registration of all cases of a disease or health condition in a defined population.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that got into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental media
Soil, water, air, biota (plants and animals), or other parts of the environment that can contain contaminants.

EPA
United States Environmental Protection Agency.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].

Exposure pathway
The route a substance takes from its source (where it began) to its end, and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a **source of contamination** (such as an abandoned business); an **environmental media and transport mechanism** (such as movement through groundwater); a **point of exposure** (such as a private well); a **route of exposure** (eating, drinking, breathing, or touching), and a **receptor population** (people potentially exposed or exposed). When all five parts are present, the exposure pathway is termed a **completed exposure pathway**.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. Many factors are considered, including health risk, costs, and what methods will work well.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with **surface water**].

Hazard
A source of potential harm from past, current, or future exposures.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with **public health assessment**].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see **route of exposure**].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

mg/kg
Milligram per kilogram.

Maximum Concentration Level (MCL)
An MCL is the highest level of a contaminant that is allowed by the EPA in public drinking water systems. MCLs are enforceable standards set as close as feasibly possible to levels below which there is no known or expected risk to health, using the best available treatment technology and taking treatment cost into consideration.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk for harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

Percentile
The value of a variable below which a certain percent of observations fall. For example, 95 out of 100 observations are expected to fall below the 95th percentile.

Point of exposure
The place where someone can contact a substance present in the environment [see **exposure pathway**].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb
Parts per billion.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time during which comments will be accepted.

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see **exposure registry** and **disease registry**].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

RfD
See reference dose.

Risk
The probability that something will cause injury or harm.

Route of exposure
The way people contact a hazardous substance. Three routes of exposure are breathing (inhalation), eating or drinking (ingestion), or contact with the skin (dermal contact).

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is several people chosen from a larger population [see **population**]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an **exposure pathway**.

Substance
A chemical.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Vapor intrusion

Vapor intrusion is a way that volatile chemicals in the ground or groundwater can get into indoor air. Volatile gases, or vapors, can move up from the groundwater into tiny pockets of air between soil grains. If these pockets are interconnected; vapors can rise and enter homes through dirt floors, foundation cracks, sump pump pits, utility conduits, floor drains, and damaged or poorly constructed plumbing. Once vapors are in the home, they may not be able to leave if the home is airtight and does not get fresh air. In some cases, the vapors can build up to harmful levels inside a home.